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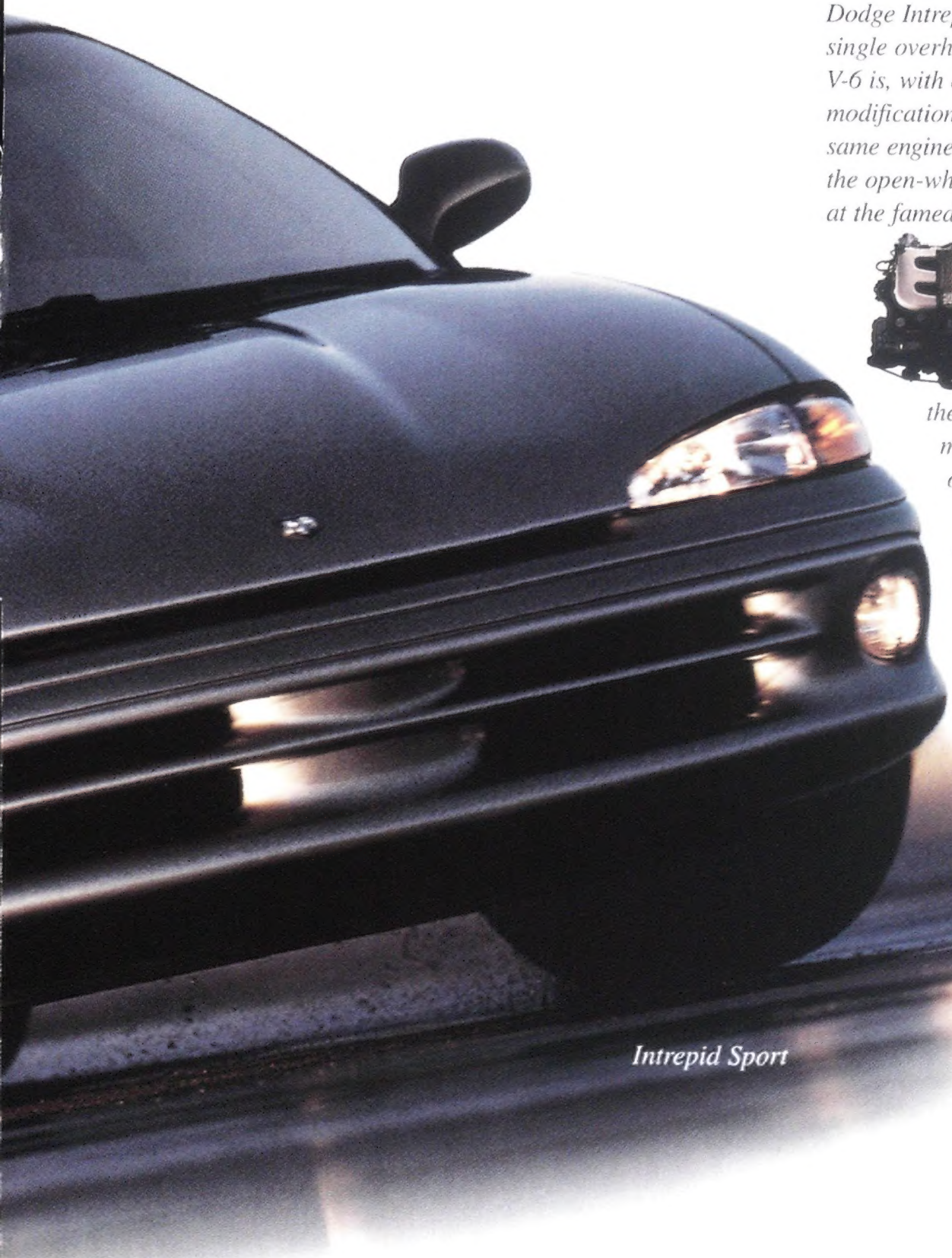

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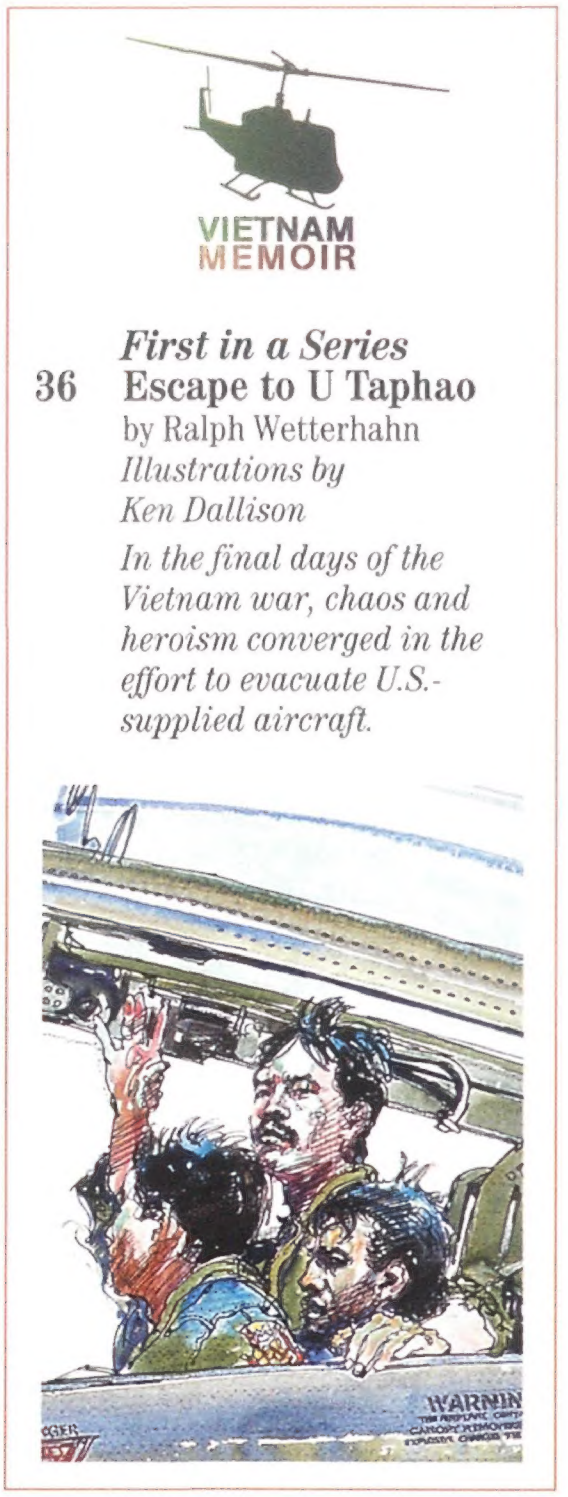

Cover:
Restorer Nick Bolea prepares a section of the Saturn V's second stage for painting in this photo by Scott Andrews.

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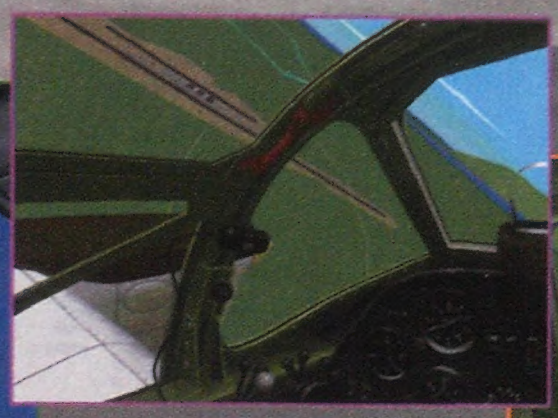

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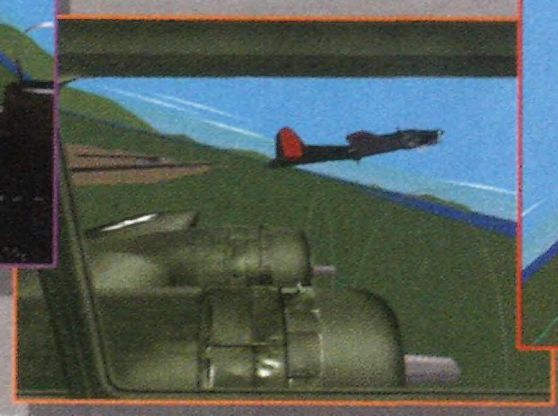

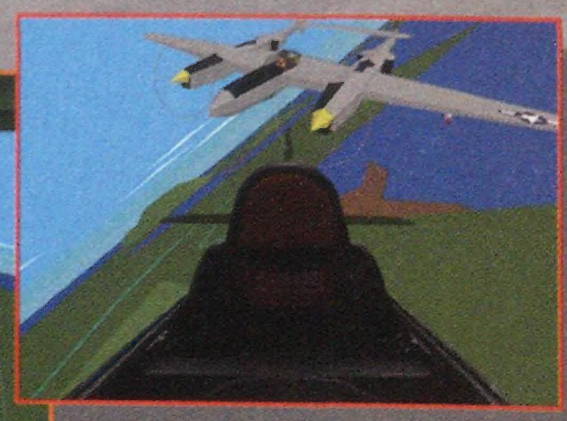

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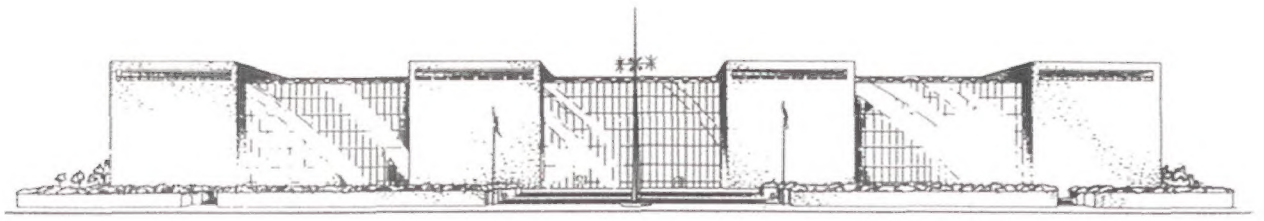

A Fresh Start

As I enter my fifth month as Director of the National Air and Space Museum, I would like to introduce myself to you, the readers of *Air & Space/Smithsonian*. Being somewhat familiar with the experiences of previous Directors, I approach this opening public dialogue cautiously. I would not like to go up in smoke before I have an opportunity to give you my views of the importance of our air and space heritage. Having held down a number of jobs during my somewhat checkered past, I'd like to start at the beginning so you will know where I come from.

My early life was spent in the shadow of pilots like Jimmy Doolittle, Roscoe Turner, Amelia Earhart, and Pancho Barnes at the Union Air Terminal at Burbank, California. I hung out at Roscoe Turner's hangar and tried to dodge the fast foot he aimed at my posterior when I tried to pet his lion, Gilmore.

When World War II came, I joined the Navy, graduating as an aviator in 1943 on the same day and at the same place as George Herbert Walker Bush (he was 11 days younger than I). I flew from Pacific Fleet carriers as a dive bomber pilot, gaining a fair share of combat experience, and then was smart enough to become a fighter pilot. They always took off first and seemed to get all the glory. But the Army Air Forces dropped two atomic bombs, and fortunately, the war ended. Job descriptions for fighter pilots are short, so I stuck with it and was in one of the first Navy jet squadrons. This was thrilling work, especially because we never had enough fuel.

We were in Hong Kong in the U.S.S. *Valley Forge* when the Korean War started, and we and a few Air Force troops had the war all to ourselves until others showed up to help out. I attended Empire Test Pilot School at Farnborough, England, before embarking on an alternating engineering test pilot/fighter pilot career with enough thrills and fun to last a lifetime. Al Shepard, John Glenn, and Wally Schirra became astronauts, but I was one of those test pilots who did not like that job description. I was also three inches too tall. And there was another war in Vietnam, where I gained responsibility, gradually working myself out of the fun jobs into management and driving ships while continuing to fly. Eventually I took charge of several aircraft carriers and went into upper management.

Our 14 year-old-son and I flew our Bonanza to London, where I had duty, and eventually flew it home to the United States and a final assignment in the Navy at Norfolk. The day after retiring from the service, I went to work manufacturing cabin-class twin-engine airplanes for Piper, where I worked for two years as plant manager, then on to Washington, D.C., where President Reagan put me on the National Transportation Safety Board. There I investigated major accidents with a very dedicated and productive crew until the President appointed me Administrator of the Federal Aviation Administration. I labored dutifully in the aviation trenches on such matters as air traffic control, airports, safety, regulation, standards, and other interesting things, all the time flying in this great airspace of ours. Then I moved to the AOPA Air Safety Foundation and eventually here to the National Air and Space Museum to write a book as a Ramsey Fellow.

Now you know me, and you know that I have dedicated my life to the aerospace world. I look forward to being creative in both air and space at the museum and am exceedingly pleased to be with you as Director. I look forward to a long and productive friendship between us. We should have a lot of fun, and if you can't get to the museum, we will try to bring it to you.

In the next issue of *Air & Space/Smithsonian* I will tell you about the odyssey that we have embarked on to create our new Dulles International Airport National Air and Space Museum Center. Here we will finally be able to work on more of our air and space artifacts to give even greater life to the museum.

—Don Engen

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LETTERS

A Low Blow to "High Flight"

As a combat pilot who flew in World War II, Korea, and Vietnam, I enjoy the poem "High Flight" every time I read it. It is displayed on my office wall.

"The Annotated High Flight" (Flights & Fancy, Aug./Sept. 1996) makes a mockery of this expressive poetry. The unknown author could have been a "Pentagon type" pilot who flies four hours per month just to collect flying pay and who had nothing better to do at his desk than try to be funny, writing drivel like that.

—Albert T. Keeler
Clinton, Maryland

Who Else Made the Mustang?

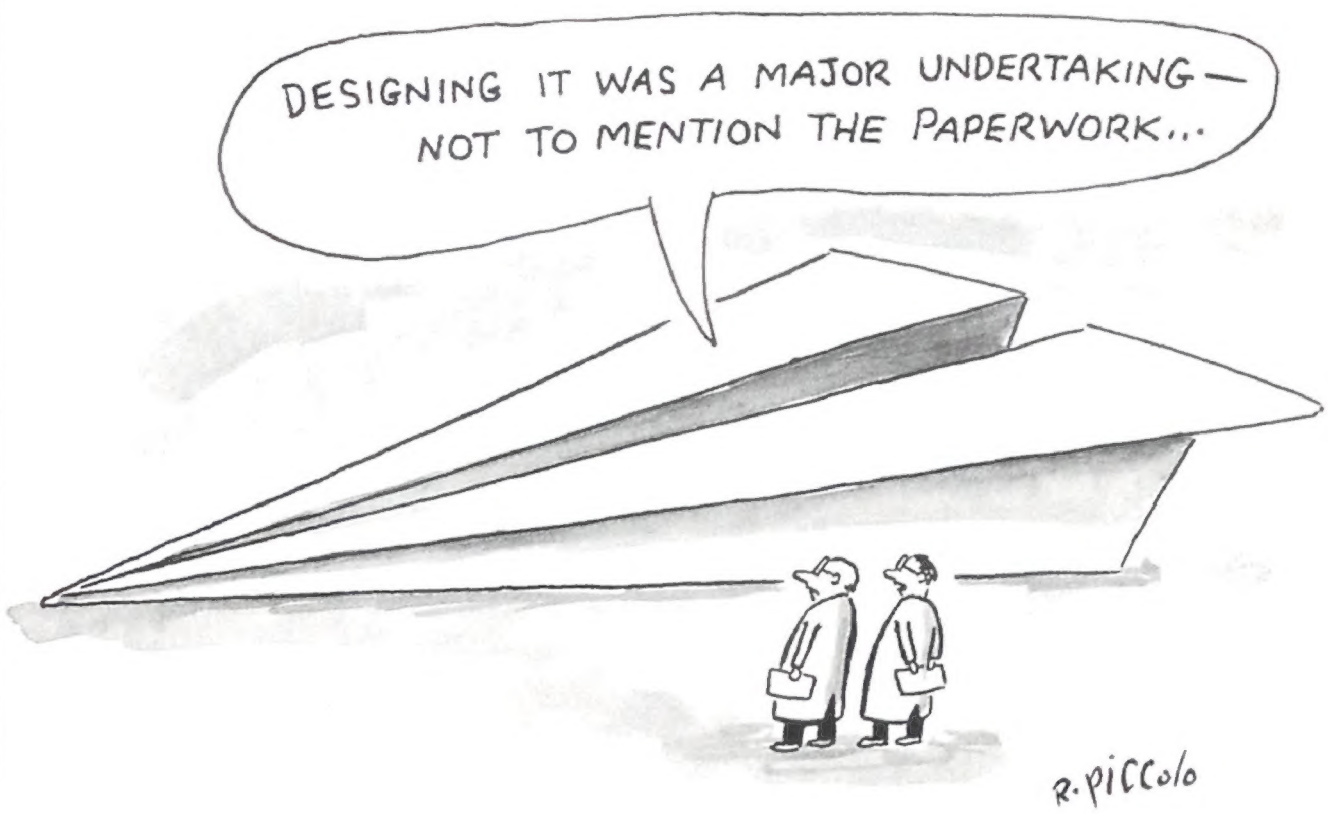
Reading "Who Made the Mustang?" (Aug./Sept. 1996) I enjoyed a rush of wonderful memories. From 1942 through 1946, I was the secretary for Gordon Thorne, chief project engineer, in the old North American Aviation engineering building at Mines Field in Hawthorne, California. At the time, all the buildings were camouflaged and had soldiers stationed on the roof with anti-aircraft guns. We worked with the project engineers for the P-51, the B-25, and the AT-6A directly under chief engineer Raymond Rice.

One of my duties was to occasionally relieve chief designer Edgar Schmued's secretary. I remember Schmued as a very dapper gentleman with a cigarette in a long holder. He and his top designers worked inside a security enclosure and the secretary sat right outside. Occasionally, when voices were raised, I could hear a few words. My favorite recollection is of hearing him shout in that strong German accent: "Any damned fool can criticize, but it takes a genius to design it in the first place!"

Who made the Mustang? Every one of us sharing these proud memories would like to feel we contributed in a tiny way.

—Eleanor Cree Edwards
Redondo Beach, California

"Who Made the Mustang?" omits mention of a key contributor: Eastman Jacobs, the engineer responsible for the P-51's remarkable wings. Working at the



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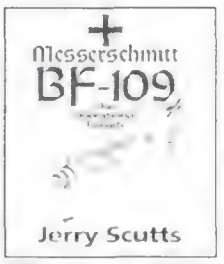

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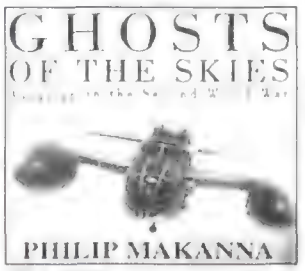

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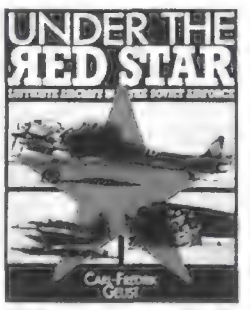

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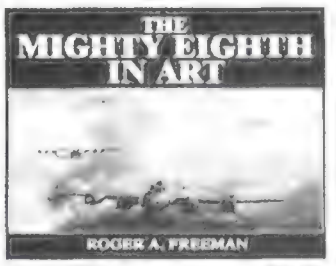

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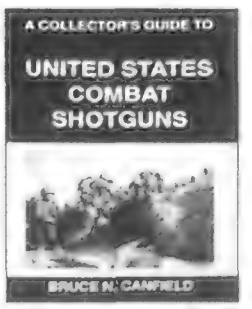

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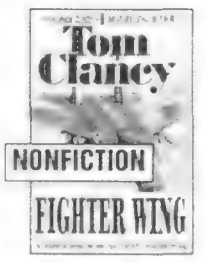

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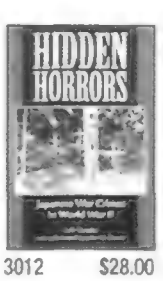

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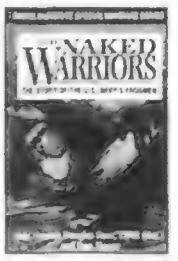

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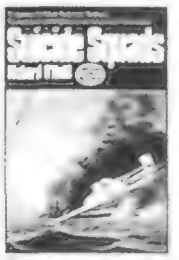

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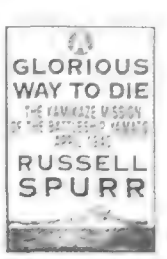

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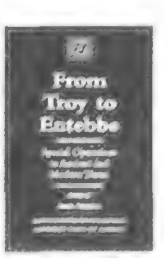

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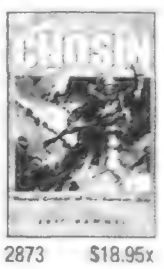

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National Advisory Committee for Aeronautics' Langley laboratory in the late 1930s, Jacobs inverted a colleague's theoretical approach and established a powerful new computational tool. Airfoils could now be designed to have specific pressure distributions.

For tests involving the thin boundary layer of air next to the new shapes' surfaces, Jacobs needed a low-turbulence wind tunnel. The terms "low turbulence" and "boundary layer" aroused no interest, but "wing icing" did, so Jacobs professed that as his research interest, and a low-turbulence tunnel got funded. Later, so did a tunnel with test-accuracy-enhancing pressure capability. The result: Wings with superior high-speed characteristics capable of sustaining drag-reducing laminar flow under ideal, non-operational conditions.

Historians say that Jacobs' work contributed greatly to the successes of the P-51 Mustang. It also helped define the modern science of airfoil design, and is still used today.

—Steven T. Corneliussen Jr.
Poquoson, Virginia

Get Out While You Can

In his essay "Promises to Keep" (June/July 1996), Carl Pilcher leaves out a very compelling reason for pursuing manned space exploration. If history is any indication, we must accept that a comet or asteroid will eventually collide with Earth, causing apocalyptic changes. By establishing ourselves on other planets and moons and eventually on other star systems as well, we can avoid the extinction of the human race.

—Ted Driver
Honolulu, Hawaii

Why Whifferdill?

Patricia Trenner's review of *Blue Angels—50 Years of Precision Flight* (Oct./Nov. 1996) mentions that the reviewer wonders where the Air Force's Thunderbirds came up with the term "whifferdill" for one of their maneuvers. My classmate Billy Higgenbotham, who was a Thunderbird in the late 1950s, told me that the whifferdill, a 90- to 270-degree reversing turn that brings the planes back into the performance area, was named after the man who had devised it.

Billy himself invented a stunt for the Thunderbirds that they still perform, and the Blue Angels have also added it to their repertoire. He called it the "*bon temps roule*," French for "good times roll." It involves two wingmen, in diamond formation, performing simultaneous rolls in opposite directions while still in formation. First time I saw it, I dropped my camera.

—Donald J. Bailey
Kimberton, Pennsylvania

Transported Through Time

Your article "B-36: Bomber at the Crossroads" (Apr./May 1996) did not mention the transport version of the B-36, the XC-99 [below]. Only one was built, and I recall watching it make its first takeoff, from Lindbergh Field in San Diego in 1947. Even when the plane was a mile away, everyone felt a strong vibration, so powerful it shattered some of the bay windows in the houses around us.

Recently, I did some research on what happened to the XC-99. Anne Hussey of the Office of History at Kelly Air Force Base in Texas told me that after being taken out of service in 1957, the XC-99 was offered for sale on the civilian market. When a buyer was not found, the Air Force donated the aircraft to the Texas chapter of the Disabled American Veterans. Early in 1958, it was towed to a site off Kelly Air Force Base, and for a short time the DAV conducted tours of the aircraft. The XC-99 was eventually passed on to other groups. For over 30 years the giant plane sat deteriorating in a grassy field adjacent to its former home.

In May 1993, a private organization called the Kelly Field Heritage Foundation bought the XC-99 and gave it to the Air Force. Now the airplane is resting on a ramp near Kelly's main runway, waiting for the day it can be restored to take its place as a memorial to the growth of our national air power.

—Gordon Olcott
Spokane, Washington

How Things Don't Fly

In the beautiful "How Do Things Fly?" foldout advertisement (Aug./Sept. 1996), the explanation of how airfoils produce lift is wrong.

It is true that when the flow over the upper surface of an airfoil is faster than that under the lower surface, it will have less pressure, thus producing lift.

However, the foldout repeats a common misconception. An upward curvature, or camber, of the airfoil will not always produce this crucial velocity difference. In fact, if an upwardly cambered airfoil is set at a sufficiently negative angle of attack, the air flowing *under* it will be faster, a situation that would produce negative lift.

What matters is that the flow align itself with the sharp airfoil trailing edge; as Martin Kutta and Nikolai Joukovsky demonstrated around the turn of the century, that alignment alone controls the difference in velocity between the upper and lower surface flows.

—E. Eugene Larrabee
Professor Emeritus,
Massachusetts Institute of Technology
Long Beach, California

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Aerodynamics Made Easy

"Out of Thin Air" (Oct./Nov. 1996) reminded me of a technique we once used to see how air flows into the intake of a T-38 with the engine at full afterburner. After brainstorming several possible techniques, one of our engineers thought of venting liquid nitrogen through a long thin tube used for washing engines. It gave great results, was easy to position any place around the inlet, did not affect the running of the engine, and visually demonstrated airflow patterns as the engine sucked in air.

—David Eichblatt
via e-mail

Don't Call the Junkman Just Yet

When I went off to college back in the 1960s, I left behind one of the most complete collections of baseball cards, Wild West cards, and comic books on the planet. My little sister took over my bedroom and promptly tossed them all out. Had she not done that, I'm sure that today I could be happily retired on the Riviera.

Now Chad Slattery's terrific article, "The Model Man" (Oct./Nov. 1996), has saved my current collection. For years, my wife has been eyeing my box full of Topping models, which includes such rarities as the F-20 and the F-16/J-79, and with each move she has said, "Do we really need this junk?" Now that she knows each of them is worth thousands, my toys are safe.

Riviera, here I come...

—Ralph F. Wetterhahn
Long Beach, California

Editors' note: Ralph Wetterhahn is the author of "Escape to U Taphao" (p. 36).

How can one tell if a model was built by Topping? Is there a catalogue of his models?

—Dennis Dillman
Houston, Texas

Chad Slattery replies: When companies allowed it, Topping models carried a small "Topping Inc." imprint underneath a wing or horizontal stabilizer; perhaps half were so marked. The company's 1961 brochure illustrates 98 distinct models, but collectors estimate that between two and three times that many were produced.

And Now a Word From the Unannointed

Neither the salvager nor the archeologist needs an internecine rivalry, yet I sensed an "us against them" tone in "Buried Treasure" (Commentary, Aug./Sept. 1996) that might lead to just that discord.

It may seem to some that archeology tainted by "salvagery" lacks academic purity. But in the real world, much of what is preserved owes its preservation to less than noble circumstances. I have the rare privilege of flying a B-17 that escaped the scrapper only because it found work bombing forest fires and mosquitoes. For some, the aircraft brings back memories of a most heroic era. The aircraft also increases their children's appreciation of history. Neither group seems to mind that not all the interior details are "correct." If a wreck can be preserved, even through the cooperation of the "unannointed," isn't that what counts?

—David F. Shaw
Penn Yan, New York

Contract Killer

I was surprised that "Opening ACTS" (Oct./Nov. 1996) did not mention the satellite's prime contractor: RCA. Though author Frank Kuznik notes that "Hughes did everything it could to kill the ACTS program," he does not point out that Hughes had lost the competition to become prime ACTS contractor.

—James R. Blankenship
New Oxford, Pennsylvania

"Well I'm sorry. I can't take a month's vacation and leave my plants."

Attention, Marauder Alumni

The B-26 Marauder Historical Society, a national non-profit organization, recently dedicated the International Archive of the B-26 Marauder. The archive seeks any documents, photographs, or other material related to B-26s and the men and women associated with them. Send materials to: International Archive of the B-26 Marauder, University of Akron, Akron, OH 44325.

Good Times on Miller Beach

I was pleased to see *Air & Space* take note of the updated version of the 1896 Chanute glider flown in Gary, Indiana, last July (Soundings, Oct./Nov. 1996). There is more to the story, however.

About a year ago, three independent groups set out to build and fly versions of Octave Chanute's classic biplane hang glider in honor of the centennial of the flight trials Chanute conducted in the sand dunes east of Chicago. One effort resulted in the glider you mentioned—the one designed by the students at Rochester Institute of Technology. Another was produced by Seattle aerodynamicist and hang glider pilot Paul Dees, who used materials and techniques of the sort employed in constructing the original 1896 craft. And finally, two Chanute replicas were built by 63 sixth graders from Orono, Maine, under the guidance of their teacher, Richard Glueck. The students constructed their gliders of spruce frames covered with parachute nylon and test-flew them as kites last June.

In July, all three teams came together for an event organized by local and national organizations. Dees flew his glider for the first time at the Warren Dunes, east of Gary, on July 26. The next day, he and the RIT team tested their gliders on the low dunes above Miller Beach. Glueck and representatives of his enterprising class were present to enjoy the events of the day, thanks to the generosity of members of the Chanute family, who were also present in considerable numbers.

I have attended a great many commemorative events over the years, but I have a tough time recalling one in

which everyone had as good a time as we had on Miller Beach that afternoon.

—Tom D. Crouch
Chairman, Aeronautics Dept.
National Air and Space Museum
Washington, D.C.

Practice Random Acts of Vigilance

"Search and Destroy: The War on Counterfeit Parts" (Oct./Nov. 1996) refers to companies attempting to get to know suppliers better by auditing them "periodically." From my experience as both an auditor and a member of audited organizations, I know that once a supplier learns your audit pattern, it can conduct one kind of operation when unobserved and a substantially different kind when audited. The better policy is to conduct audits on a random basis.

—Robert K. Dann
Gaithersburg, Maryland

Helicops to the Rescue

After 26 years of flying with the Baltimore Police Department, I can vouch for the effectiveness of police-operated aircraft ("The Helicops," Aug./Sept. 1996). Our records indicate that arrest assists to ground units average 750 a year. These lockups would not have been made had it not been for the observations passed on to ground units by "Foxtrot" crews.

—Barry W. Wood
Baltimore, Maryland

An Innocent Explanation

As a psychologist, I was interested in Ed Peden's psychological views of missile warfare ("Bless Our Happy Missile Silo," Oct./Nov. 1996). Peden believes that the raised Atlas missile is a symbol of "the ultimate male ego's warped will" and "remarkably phallic." I am far from an expert in missiles and missile technology, but it seems to me that firing a missile in the vertical position could be interpreted as simply the best way to achieve a successful launch.

I suppose a missile could be fired upside down, but the sexual connotations are too much for me to consider.

—Mario A. Benassi
Burlington, Wisconsin

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When the Air Force Thunderbirds, the Royal Canadian Air Force Snowbirds, and the Army Golden Knights met last September for a private performance at the home base of the Navy Blue Angels in Pensacola, Florida, it was not a competition to label anyone The Best. Nor was it even an airshow, but rather, as Navy spokesman Lieutenant Commander John Kirby said, "an exchange of information." In fact, to prevent any show-stealing, military regulations prohibit the two U.S. jet teams from performing within 150 square miles of one another simultaneously, except on this one day every year, a tradition that started in the early 1950s.

Observers—mostly Blue Angels support crews and their families and friends, armed with a score of video cameras—were in place at the decidedly un-airshow start time of 7:30 a.m. The Thunderbirds were up first. They marched out with military precision to recorded patriotic music while a narrator kept up a breathless commentary. After zipping into G-suits, they climbed into their F-16s and rocketed off in supertight formation. Along for the ride were one pilot from the Angels and another from the Snowbirds, strapped into the rear seats of two F-16 trainers. When the team landed, the audience gave it a smattering of polite applause.

Next up were the Golden Knights, whose crack parachutists performed solo and formation freefall jumps and parachute cutaways. (No members of other demo teams saw fit to tag along in order to "exchange information.") The Army team ended its performance with a multiple-banner jump honoring the other teams. The Thunderbirds' flag evoked another round of golf tournament response, while the Angels' banner brought a rousing ovation.

Then came the Snowbirds. The martial music was replaced by the familiar strains of rock band Dire Straits. Because the team uses nine Canadair CT-114 jet trainers, it can create formations unheard of by other service groups, most of which fly six aircraft: the Champagne Glass, for example, and the Maple Leaf. But conventional wisdom is that in formation flights, size doesn't count. What counts is speed and decibels, and any American present would say the Snowbirds lacked both.

After the team landed, a reporter asked number-nine pilot Jean Guilbalt why the Canadians' flightsuits weren't as tight as the Americans.' "They gained some weight during the season?" he ventured.

About 11 a.m. the Angels marched out to their F-18s and flew their normal show, accompanied by pilots from the other demonstration teams. By the end of the production, members of the audience were suffering from strained necks and tinnitus, but they managed to give the hometown team the loudest applause of the day. Next year the applause meter is bound to record the opposite pattern, when information exchange day moves to the Thunderbirds' home field at Nellis Air Force Base in Nevada.

After the non-airshow, all pilots were gracious about their counterparts. One Thunderbird pilot allowed there was "a friendly rivalry" between the Air Force and Navy teams, adding perhaps facetiously that when the two teams met later at a local bar called Trader Jon's, "I'm sure no alcohol would be involved."

By the way, in the only sanctioned competition of the day, the traditional afternoon softball game, the Thunderbirds maintenance team beat its Blues counterpart 11 to 5.

—Phil Scott

Supercooled

Stock car driver Rusty Wallace can easily imagine the blistering 3,000-degree heat of atmospheric reentry: The floorboard of his no. 2 Ford felt just about that hot every time he took the car for a 200-mph spin around a track.

Then a NASA official with a passion for racing offered to insulate the Thunderbird with scraps of thermal blankets developed for the space shuttle.

"When you're out there running a 500-mile race, your feet are going 'Ouch ouch ouch!' This is going to be a lot better," says Wallace, a space enthusiast who "never thought in a million years" that NASA and NASCAR would get together. Then, in 1995, Jay Honeycutt, director of the Kennedy Space Center, invited Wallace, race team owner Roger Penske, and his crew to the center for months of hush-hush work that culminated in a test drive last April at the Daytona International Speedway in Florida.

Temperatures rise as high as 160 degrees Fahrenheit inside the driver's cockpit during a race, but "I did a 20-lap run with not one bit of perspiration on my face," Wallace says. "I was totally impressed."

Although drivers are cooled with forced-air systems and protected by fire-retardant suits, they have been burned and blistered by the tremendous heat transferred through the engine firewall, transmission tunnel, and floor. In the Daytona test, insulation mounted on those areas of Wallace's car reduced temperatures 30 to 50 degrees in the cockpit and up to 120 degrees on structural components connected to the exhaust system. The same type of blanket insulation, developed by Rockwell International, protects the space shuttle's upper wing surfaces, fuselage, and payload bay doors from the friction-induced heat it encounters as it returns to Earth.

Wallace has raced several times with the insulation, and he says the cooler temperatures improve engine performance as well as safety on the track. Drivers are more alert. "Tempers tend to flare," he says. "You're going to get a safer race because the drivers are paying attention."

Wallace's success paved the way for BSR/TPS Products Inc. of Mooresville, North Carolina, to manufacture race car insulation kits. The kits, to be distributed soon through a nationwide catalogue system, will be the first product to bear a "Take Up Space" seal.

The seal certifies that a product was developed directly from U.S. space program technology. The certification initiative is sponsored by Mission HOME, which stands for Harvesting Opportunity for Mother Earth, a campaign by the U.S. Space Foundation and the National Space Society to educate the public about the spin-off benefits of exploring space. Companies earn the right to use the seal by submitting their products for review by a panel of technology experts.

—Beth Dickey

FORT WORTH STAR-TELEGRAM (2)

Dallas-Forth Worth International pulled out all the stops last fall to celebrate the opening of a new runway at the mega-airport. On September 28, 5,000 runners turned out for a five-kilometer Run the Runway race, with the start and finish lines marked by a Delta Airlines 767. Winners received trophies fashioned from core samples of the runway. The 8,500-foot runway, which brings DFW's total to seven, was opened to traffic on October 1, when J. Jan Collmer, vice chairman of the airport board, cut the traditional ribbon, mounted on poles, with the propeller of his aerobatic Extra 300/L. The first aircraft to land on Runway 17L-35R, an American Airlines flight from Las Vegas, taxied beneath an arch formed by jets of water from fire trucks. Passengers and crew were presented with souvenir key chains as they de-planed.

UPDATE

Making It Stick

NASA's laminar flow experiments with its supersonic delta-wing F-16XL have produced "terrific results," says Jeffrey Lavell, project manager of the Supersonic Laminar Flow Control program at the Langley Research Center in Virginia ("Go With the Flow," June/July 1995). A large titanium panel with 10 million laser-cut holes was applied to the upper surface of the aircraft's left wing. Suction pulled the surface layer of air through the perforated panel, achieving a "significant amount of laminar flow," says Lavell. The aircraft made some 40 Mach 2 test flights.

NASA's Cattle Call

Back when only cows jumped over the moon, hundreds of cattle roamed a 1,600-acre pasture south of Houston. That was before NASA broke ground for its Manned Spacecraft Center in the early 1960s.

More than 30 years later, with the Apollo flights a waning memory, the cattle are returning to graze. This time, just a handful of longhorns will move on to a small teaching farm scheduled to open next March on the western border of the present-day Johnson Space Center.

"We're kind of returning to the future," says center director George Abbey, who came up with a plan to put students from nearby high schools in charge of a 60-acre farm complete with vegetable gardens, fruit orchards, fish ponds, and five longhorns. NASA is donating the land and engineering expertise, including site preparation and utility connections, at an estimated cost of $50,000. The Clear Creek Independent School District will provide the instructors and farm equipment.

The cattle belong to Houston Livestock & Rodeo. Chairman Dan Gattis says the project is rooted in a desire to create a bucolic view for tourists visiting the NASA center. The pasture is adjacent to a rocket park through which the attraction's tour tram passes. "You've got the old Texas longhorn, which is really more of a symbol than it is our modern-day cattle," Gattis says, "then you've got the Saturn V rocket and the center that controls the flights of the shuttle. It makes a really nice scene."

Typically, the education projects NASA sponsors are related, at least remotely, to the study of microgravity. But space center master planner Don Holick, an architect and punster who introduces himself as "the head of the steer-ing committee," insists there is a space connection. "Through agricultural education, students learn science, mathematics and technology skills that are the cornerstones of expertise that will be needed to run the space program in the future," Holick says, reading from a statement.

The farm embodies NASA's new emphasis on community involvement. Holick admits the longhorn project is "kind of pushing the envelope" for NASA, but he adds that "if we hope to survive in years to come, there have to be community projects. We just can't stand alone."

Clear Creek school district superintendent John Wilson says the project has opened doors to other NASA resources that have benefited his district's faculty. "It's not just a picture of longhorn cattle out there," he says. "The real imagery in this partnership is to provide a real world-class experience for the students. At the same time, it provides a little uniqueness to JSC, but after all, this is Texas."

—Beth Dickey

NASA

UPDATE

Stearmans at War

Stearman enthusiasts ("Back to the Basics," Oct./Nov. 1994) can now combine a joyride in the aircraft with "the thrills of open cockpit warfare...using World War I tactics," courtesy of Classic Dogfights. The Hemet, California company offers a "full combat air package"—briefings, aerial combat session with replica machine guns and smoke systems, and videotape of the flight—for $399. A non-combat ride is $199. Call (909) 658-1116.

The Rocketeers Club

They gathered at a nondescript New Jersey restaurant last October to recall their youth and the achievements of 50-odd years. But unlike reunions of veterans who swap tales of flak-filled skies, at this reunion the memories were of combustion chambers, trials and errors, and pride: The workers at Reaction Motors Incorporated launched the Space Age with Black Betsy, the rocket engine that propelled the Bell X-1 beyond Mach 1 in 1947.

"We knew that we were involved in something wondrous, something monumental," said RMI aeronautical engineer Harry W. Burdett Jr., "and when man first landed on the moon, there was a little bit of each of us with him."

In the 1930s, the New York-based American Rocket Society brought together a group of young scientists, engineers, and artisans who called themselves Rocketeers; later, they formed the core of RMI (see "Bringing Up Betsy," Dec. 1988/Jan. 1989). "We'd sneak across the Hudson to Jersey to light off and test-fire these creations," Burdett said. "It was secluded, and we were usually one step ahead of the police and the local fire marshals. You can bet we never went back to the same place twice."

Testing was also dicey at RMI's rural setting in New Jersey, said Lois Seaman, whose husband Bob was RMI's chief engineer. "When the kids were small, we'd get these phone calls in the middle of the night, and there was never anyone on the line." With production schedules running way behind, Bob Seaman explained, engine tests were often carried on well into the night. "I guess our neighbors up around Lake Denmark decided that if they weren't going to get any sleep, neither were we."

"I'll always remember the blast of those rockets at night," said Benjamin Misajet, a project electrician, "how they reached out with all the colors of the rainbow. There was power and beauty in that. You couldn't walk away from such a sight and be unchanged the rest of your days."

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RMI became a division of Thiokol Chemical in 1958 and closed in 1972 after it ceased to turn a profit, but to its workers, it will always be Reaction Motors. Burdett explains that the name came from Newton's third law of motion: For every action there is an equal and opposite reaction. "It was a grand name," Burdett says. But "Motors" misled some callers. "The only problem was that for months and months after we'd opened, we'd invariably get phone calls asking 'Do you guys do front-end alignments?' "

—Albert J. Parisi

Baby Huey

The world's largest peanut? No, the world's smallest helicopter. At least its builders think it is. They haven't bothered to check with any official record-keeping organization, but it's hard to imagine a working helicopter itty-bittier than this one. It weighs just over a hundredth of an ounce, measures less than an inch end to end, and is three-tenths of an inch high.

Technicians at the Institut für Mikrotechnik in Mainz, Germany, which specializes in tiny technology, wanted to prove the power of their new micromotors, which spin at 400,000 rpm and are normally used in things like laser scanners and ultrasound catheters. They decided on a demonstration that was not so much practical as designed "to show people that we have fun in our work," according to IMM staffer Ellen Straub.

The helicopter consists of two micromotors mounted on an aluminum body, with painted paper rotors shaped by heating in a mold. On its maiden flight, the microcraft climbed a whopping five inches up a guide wire, its little rotors beating away at 40,000 rpm. IMM's Heinz Lehr says controlled flight would have been a much more difficult proposition, but he already has thoughts of expanding his Lilliputian air force, this time with an airplane.

—Tony Reichhardt

IMM

UPDATE

Down...

• The asteroid probe Clementine 2 ("Cheap Thrills," Soundings, June/July 1996), slated for launch in 1998, lost half its funding when the 1997 appropriations bill was signed into law. The program was one of several whose budgets were slashed to reduce $1 billion in defense department overspending, but insiders point out that the Pentagon is not particularly supportive of science missions with no military applications.

• Kiwi International Airlines ("Flier's Market," Oct./Nov. 1993) filed for Chapter 11 bankruptcy last September and suspended scheduled service pending approval of a new operating plan.

...and Out

• The final Fulton Surface-to-Air Recovery System mission ("Queasy Rider," Above & Beyond, Aug./Sept. 1996) was carried out last September when the Air Force's Eighth Special Operations Squadron, using Lockheed C-130s, recovered its last packages at Hurlburt Field in Florida. The squadron had maintained Fulton Recovery proficiency for the last 30 years. Air-refueled helicopters will perform future recovery missions.

• The General Dynamics F-111, believed to be the only Air Force craft with no official name ("The Name Game," Aug./Sept. 1992), has been retired after 30 years and posthumously named Aardvark, its nickname since 1969.

• Citing budget constraints, the European Space Agency shut down the International Ultraviolet Explorer last September ("Blast From the Past," Aug./Sept. 1988). The IUE was launched in 1978 and was described by astrophysicist Freeman Dyson as "a little half-meter mirror sitting in the sky, unnoticed by the public, pouring out results." Its most recent application was observing the nucleus of Comet Hyakutake last March.

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The First Black Airplane

Toward the end of 1942, engineers and technicians working for Bell Aircraft at Ford Motor's Main Street plant in Buffalo, New York, were close to completing the construction of a modest-looking twin-engine fighter. Designated the XP-59A Airacomet, the aircraft was not as fast as the P-38 Lightning, nor would it become as famous as the P-51 Mustang, but it had one quality those other World War II fighters lacked. The XP-59A was powered by centrifugal-flow jet engines, making it the United States' first turbojet-powered airplane.

This was revolutionary technology—precious enough to convince General Henry "Hap" Arnold, chief of the U.S. Army Air Forces, that the project required exceptionally tight security. Hoping to mislead unauthorized observers into thinking that the fighter was a descendant of an earlier, propeller-driven prototype, the airplane's designers named it after a defunct Bell Aircraft project—the piston-powered XP-59 fighter. Engineering drawings for the Airacomet were deliberately mislabeled (drawings of exhaust pipes were marked "heater ducts," for example), and the design facility at the Main Street plant was vigilantly guarded. To further disguise the airplane's technology, the Airacomet was fitted with a mock propeller, which was removed before flight and reinstalled afterward. The secrecy surrounding its development gave the Airacomet the distinction of being the United States' first "black," or top-secret, airplane.

The original XP-59A (a total of three were built) now hangs from the ceiling in the National Air and Space Museum's Milestones of Flight gallery, where its neighbors include the Wright *Flyer* and the Gemini 4 capsule. Painted a reserved, no-gloss military green with a gray underbelly—an appropriate color scheme for an aircraft that had to remain unknown—the Airacomet arrived at its current location following the dismantling of the Flight Testing gallery (which now houses the new "How Things Fly" exhibit). Hanging an aircraft such as the 7,000-pound Airacomet, however, is not like stringing up a mobile. The effort requires a great deal of planning, hand-eye coordination, and methodically applied muscle power.

"We could come in here with a crane and pick this thing up and *zip*, it would be up in no time," says Tom Alison, the curator overseeing the display of the Airacomet. But, he explains, accomplishing such a seemingly simple task would require endless hours of preparation. The weight of the crane alone—38,000 pounds—would have necessitated hiring an engineering consultant, and the Museum would have had to close its underground parking garage long enough to brace a section of floor in the Milestones gallery. Not wanting to face such a delay, Museum officials chose instead to install the XP-

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59A Airacomet with the help of a few good men and a grip hoist.

At 7 p.m. last July 18, after the Museum had closed, Operation Airacomet Lift began. The crew started off by attaching the XP-59A to a series of cables, then lifting it from the floor mere inches at a time. Though the airplane's tail was raised with the help of a machine, workers got no assistance with the wings, which they raised with a man-powered pulley and the grip hoist, a mechanism resembling an automobile jack. To keep the Airacomet from swinging into the wall as it was slowly drawn toward the ceiling, workers steadied it with ropes attached to the airplane's wings and nose. It was a painstaking process that took eight people eight hours to complete. Now the XP-59A makes its home in one of the world's most visited galleries—a fitting retirement for an airplane that inspired such high hopes among its designers.

Though the Airacomet's jet engines, General Electric I-As, were cutting-edge 50 years ago, they are somewhat lackluster by today's standards. They had an operating life of only five hours, and each offered a mere 1,250 pounds of thrust—a feeble breeze compared to the 90,000-pound gale generated by today's biggest fanjet engines. General Electric engineers had modeled the I-A after the Whittle W.1X, which powered Britain's first jet aircraft, the Gloster E.28/39 Pioneer. The Pioneer's first test run was conducted in 1941, but the honor of the world's first jet flight belongs to Germany, whose He 178 flew on August 27, 1939. Nevertheless, for the United States, the Airacomet was, in the words of sound barrier pioneer Chuck Yeager, "a quantum leap into aviation technology."

Flight testing began on October 1, 1942, at Muroc, a dry lake bed in southern California. Bell Aircraft's chief test pilot, Robert M. Stanley, was the first to fly the aircraft, taking it to a cautious altitude of only 100 feet on the first four flights. The following day, the XP-59A reached 10,000 feet without incident.

Despite the optimism of its developers, the XP-59A never managed to find glory as a fighter. Even many of the engineers and other personnel who had a hand in its creation were disappointed by the Airacomet. Despite being jet-powered, the craft was unable to compete with the faster propeller-driven fighters of the day. "From a performance perspective it wasn't a great success," says Alison. "For what it was designed for it was a success: It proved that we could build [jet airplanes] and fly them. Even though it didn't have the high level of performance, it proved the concept."

Though the XP-59A's immediate descendants—twin-jet P-59s—were retired after serving as military trainers for less than a year, the Airacomet's legacy moved the United States from the propeller age into a new age of aviation history. It was a transition that took some getting used to: Many people believed a propeller to be as important to an airplane as wings were to a bird. "Just the idea of seeing an airplane flying through the air without a propeller on it was very startling for many people," says Alison.

The propeller-less Airacomet was surprising in other ways as well. Of his 20-minute voyage into the Jet Age, Colonel Laurence C. Craigie, the second pilot to fly the XP-59A, recalled: "I didn't get very high. I didn't go very fast. The most vivid impression I received, after a very long takeoff run, occurred at the moment we broke contact with the ground—it was so quiet."

—Becki Bell

MARK AVINO

No one could ever accuse Roscoe Turner of being dull. The great 1930s air racing pilot attracted lots of publicity with his flamboyant antics—most notably a six-month stint in which he flew with a lion cub named Gilmore in the copilot's seat. Turner's theatrics extended to his flying attire: riding breeches, a custom-made tunic cut to resemble a British officer's uniform, and buttons bearing his initials. On his chest, Turner wore a pair of wings, custom-made from 10-kt. gold and diamonds. Eventually, the diamonds were replaced with rhinestones. In 1996, the rhinestone-studded wings (appraised at $2,100), plus the diamonds (value undetermined), were donated to the Museum by the estate of his widow, Madonna Turner.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700, Mon.–Sat., 9 a.m.–4 p.m.; TTY (202) 357-1729.

December 12 G.E. Aviation Lecture: "U.S. Navy Airship Development." William D. Harkins, an airship patrol commander with the U.S. Navy during World War II, discusses the operations of Navy airships searching for German submarines off the U.S. coast during the war. Langley Theater, 7:30 p.m.

January 23 G.E. Aviation Lecture: "Iron Claw." Gulf war veteran Sherman Baldwin, who was assigned to an EA-6B Prowler squadron aboard the U.S.S. *Midway*, will talk about his squadron's wartime mission: identifying, jamming, and destroying enemy radar. After the lecture, Baldwin will sign copies of his new book, *Iron Claw*, whose title is taken from his squadron's call sign. Langley Theater, 7:30 p.m.

New Exhibit The National Air and Space Museum celebrates the 50th anniversary of the U.S. Air Force with a special exhibit featuring a North American F-86A Sabre, works from the Air Force art collection, airplane models, and a new mural. The exhibit, which opened on November 22, runs through May 1997. Gallery 104 in the Museum's west end.

National Air and Space Society

As a member of the National Air and Space Society, your support will help the Museum's efforts to build an extension at Dulles International Airport, which will display such artifacts as an SR-71 Blackbird and the space shuttle *Enterprise*. To receive additional information, call (202) 786-2643 or write to the National Air and Space Society, NASM, Room 3520-B, MRC 310, Washington, DC 20560.

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The Grumman on the Moore Farm

PHOTOGRAPHS COURTESY BERNARD RYAN JR.

The author vividly remembers a summer day in 1940 when a Navy captain landed his fighter on a neighbor's farm. Three photos from his scrapbook document the visiting Grumman F3F, the Navy's last carrier-based biplane, and the excitement it caused.

One morning last year, I read in the *New York Times* that Admiral Walter F. Boone, whose 43-year career in the U.S. Navy began in World War I, had died at 97. The obituary reviewed his career, citing his service as executive officer aboard the carrier *Enterprise* in World War II, his fighting at Midway, Guadalcanal, and the Eastern Solomons, his Silver Star for action in the Battle of Santa Cruz, and his duty as commanding officer on the carrier *Yorktown* in the Okinawa campaign.

Instantly I am a boy back in my hometown in western New York State. It is a brilliant June day in 1940. My mother's friend Elizabeth Wilcox lives up on South Main Street, almost at the town line, beyond which stretch the broad, open fields of Orleans County farmland. About lunchtime, a deafening roar sweeps over the town from south to north, dies down, then returns in the opposite direction. I dash outside and look up. Nothing but blue sky.

Someone phones Mama. Fred Boone, a Navy captain who is married to Elizabeth's sister, has landed his airplane on the Moore farm. We jump into the car, drive through town and up South Main. The Moore farm is the first outside the town line, only five or six houses beyond the Wilcoxes. Cars are pulling into the Moore driveway and past the barns into the long field that stretches east. The airplane stands solidly, a giant toy in the center of a broad space all its own. The ground is dusty, a field of stubble after the harvesting of the June crop of wheat.

Cars park far back from it. People get out, walking slowly, circling the airplane and studying it. Some seem a little sheepish, as if they know it is silly to drop everything and come running to see an airplane.

It is the Navy's Grumman F3F fighter, which would be its last carrier-based biplane. The fat bosom below the lower wing is indented with great cup-like holes where the wheels can be tucked. I gaze up at the shiny propeller. The three blades must be eight feet long. Behind it is the huge radial engine, angled toward

the sky as the airplane, almost all engine, sits nose-high, its stubby fuselage tapering back to the tiny tailwheel, which also retracts (I know this because I have *Popular Aviation* illustrations on my bedroom walls).

While I admire the airplane, Mama starts chatting with a man at the edge of the crowd—it's Ferrin Fraser, one of the writers of the "Little Orphan Annie" radio show.

Here comes Captain Boone, strolling across the field from where its far corner meets the Wilcoxes' back yard. He is a picture-book flier: reddish blond hair, ruddy complexion, sharp, well-trimmed mustache, crow's feet at the corners of the eyes, brown leather jacket. Elizabeth Wilcox is with him, and tucked under his arm is a shoebox.

He greets Mama at the edge of the crowd—they've met before. She introduces me. He gestures with the shoebox—Elizabeth has made him lunch. He doesn't have time for a sit-down meal; he's putting in his monthly flight time and has to get this buggy back to the Anacostia base on the edge of Washington by 4 p.m. But on a day like this he couldn't resist flying north to our part of the world. He steps to the airplane and the crowd shyly edges away. He grasps the padded rim of the cockpit, puts his right foot into an indented step in the white fuselage, and swings aboard. Now he pulls on his leather helmet and adjusts the goggles on his forehead.

A bystander pulls the big propeller through. Then a sudden cough, a burst of blue smoke between the wheels, a tremendous roar, and the propeller is invisible.

The tail swings around sharply so the engine is facing the crowd. Captain Boone has set the brakes and is doing his engine check. The roar increases from tremendous to deafening, and a huge cloud of brown dust billows behind the airplane, rising into the sky far down the field. Through it I see Mama and Ferrin Fraser. Somehow, engrossed in conversation, they have wandered to the side of the field directly behind the airplane, in the full blast of the engine. Now the billows of dust are so thick I can no longer see them.

I wonder if Fred Boone knows they are there. When he starts to taxi, he won't be able to see anything straight ahead. Is the Grumman going to run into them when it turns? Should I run around behind the airplane and tell them which way to go? How do I know which way?

The roar dies, the engine is at idle. The storm of dust moves on down the field, revealing Mama and Mr. Fraser in the same spot, chatting as if they are at a tea party. Now Fred Boone guns the engine and the tail of the airplane swings away from them. The Grumman turns in a tight circle before the crowd and, bumping and wobbling on the rough field, moves off to the east. Mama and Mr. Fraser stroll back toward the rest of us, each wearing a coat of brown dust.

The airplane is a toy in the distance, far down the long field. It is directly in front of the woods, turning toward us again. I can see it growing larger before I hear the roar. Suddenly the great sound bursts at us, and in seconds Fred Boone's Grumman zooms overhead, maybe 75 feet high. We pivot in unison to watch him climb to the west. Now he turns south, toward Washington, 500 miles away.

But he keeps turning. He's in a climbing turn, moving up fast, already not much larger than a speck almost directly above us, the sound a quiet purr.

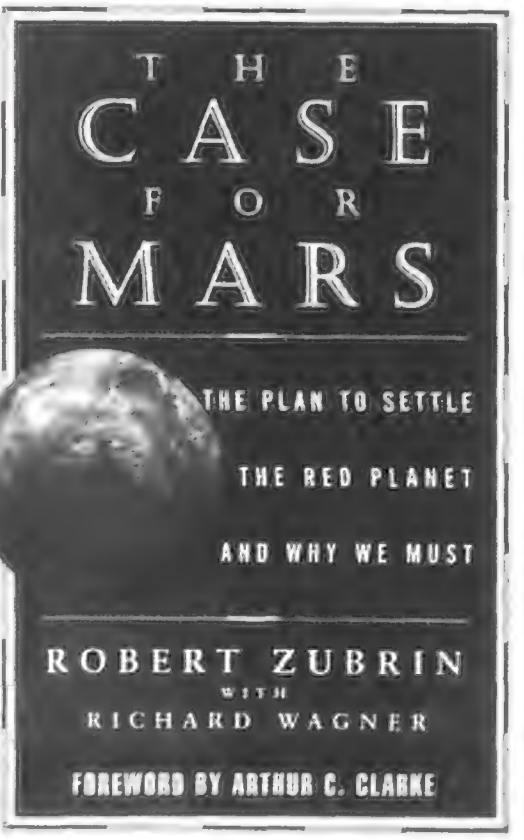
Then, a growing roar. The deep, throaty sound of power, louder still. The speck is an airplane, a biplane, the Grumman coming at us, a power dive right out of the movie *Test Pilot*.

He pulls out just as we can make out the Navy insignia on the underside of the wings. The wheels are sucked up tight against the belly. Some people are running, some are frozen in place, some are grinning, others are horrified. Fred Boone is heading west again, climbing rapidly, banking left to head south as he climbs. In moments the Grumman is again a dot, the engine a drone.

Reading his obituary, I think of Fred Boone alone in his cockpit. In the brilliant afternoon sunlight, he is opening the shoebox, unwrapping the waxed paper, and munching his egg salad sandwiches as he barrels toward Anacostia and, beyond it, four years of dustless flight decks across the broad Pacific.

—Bernard Ryan Jr.

"Bob Zubrin is the Christopher Columbus of Mars."
—Dr. Chris McKay, scientist, NASA Center for Mars Exploration



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Pepsi's Air War

You might think of John Leonard as a modern-day Don Quixote, tilting at the corporate might of Pepsi-Cola. His quest is not for the hand of Dulcinea but for a fighter/attack aircraft, the McDonnell Douglas Harrier.

As befits a contemporary epic, inspiration came to Leonard via television. In October 1995 he saw a commercial for the Pepsi Stuff campaign, in which points collected from Pepsi products could be exchanged for catalogue merchandise. The ad featured a teenager who has a T-shirt, leather jacket, and shades, all acquired with Pepsi points, as well as a Harrier, shown with a price of seven million points. After the Harrier makes its vertical descent onto high school grounds, the teen looks up from the controls and says, "Sure beats the bus."

Where Pepsi and most viewers saw a spoof, Leonard, a 21-year-old Seattle college student, says he saw a genuine offer—and an opportunity to make some money selling Harrier rides and contracting the fighter to airshows and filmmakers. He developed a business plan and lined up investors. Last March, availing himself of Pepsi's offer to sell points for 10 cents apiece, Leonard submitted a check for just over $700,000 (scrupulously including the $10 shipping and handling fee) and waited for word about his jet.

Pepsi was not amused. It returned his check and included coupons for three cases of Pepsi. Leonard persisted and—surprise—the whole affair ended up in court. Complaints by each side are pending.

Pepsi maintains that Leonard's claim is absurd, but just suppose the company did feel compelled to cough up a Harrier. Could it be done? Harriers are no longer manufactured, and it would take an order of at least 12 to restart the production line. Leonard, being a reasonable guy, would accept a used model, but the U.S. military is unwilling to part with any in its inventory. Foreign military, such as the Spanish and Italian navies, fly Harriers, but even if a government could be found that's eager to hand over one of its frontline fighters for ready cash, there's still the task of getting the purchased aircraft past the U.S. Customs Service and Department of State.

Leonard says he knows of a source where Pepsi could get him a Harrier, though he's a little vague on the details. If Pepsi did comply, Leonard may come to wish he'd never laid eyes on his Pepsi Stuff prize. The IRS would be quite interested in his windfall, since the difference between what he paid and the Harrier's fair market value would be a breathtaking capital gain. A new Harrier last sold for more than $30 million, though a previously owned model would have a somewhat lower value. According to David Williams, a Potomac, Maryland accountant, Leonard would immediately owe roughly 45 percent of the gain.

Before Leonard could start renting out his Harrier, he would need Federal Aviation Administration approval of both his aircraft and any passenger-carrying operation. Once in business he would find, as Marine Corps spokesman Captain Sean Gibson puts it, "The Harrier is not exactly economical transportation." It consumes jet fuel at up to 11.4 gallons per minute. A tankful, good for about two hours of flight, costs more than $1,400.

The Harrier is also punishing on the ears. "I'd swear sometimes that it would stay airborne on the noise alone," recalls Colonel Jack P. Monroe Jr., a former Harrier pilot and now head of the Marine Corps Aviation Association.

And Leonard would be wise to get a lot of insurance. A jet that lands like a helicopter can provide close-air support in combat, but that vectored thrust carries a price. Even with the extensive training required of Harrier pilots, it doesn't take much for something to go wrong during the transition from horizontal to vertical flight or during landing.

If Leonard's plans for the Harrier don't work out, he says he could always sell the aircraft to a broker at a profit. But critics charge that what he's really after is publicity. Leonard replies that he never went public until Pepsi took him to court for filing a frivolous claim, and while the attention was initially enjoyable, it's now a burden: "I've had my two minutes of fame," he says. "After this, I feel for movie stars." To those who say he's abusing the legal system, Leonard counters that Pepsi is the one guilty of abuse: "This is a company that made an offer and is using the courts to try to get out of it."

But Pepsi spokesman Jon Harris insists there was no offer, because the spot was "one of the most obviously farcical scenarios that's appeared on TV in recent years." In the fanciful world of Pepsi commercials, dogs talk, a goldfish performs tricks, and a monkey drives a jeep. "The monkey hasn't come forward asking for residuals," says Harris, "but we'll keep you posted."

—Lester A. Reingold

RICHARD THOMPSON

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Saturn Rising

Imposing even in repose, the Saturn V's mighty first stage undergoes a facelift at its Kennedy Space Center home. The numbered segments near the distinctive F-1 engines are heat shield panels.

The Saturn V moon rocket wasn't built to take neglect lying down.

by Frank Winter and Scott Wirz

Photographs by Scott Andrews

NASA

BERNIE HUNT

The first stage went on display alone at Kennedy in 1974 (top); the full vehicle, in 1976 (opposite). But exposure to the elements took its toll, as corroded cable inside stage two (above) shows.

Picture yourself washing your car. It's an easy enough job, right? Something you could do in about 45 minutes on a Saturday afternoon. Now imagine that you are washing 50 cars with a toothbrush while working 45 feet in the air inside a greenhouse. That should give you an idea of what it took to restore the giant Saturn V moon rocket now on display at the Kennedy Space Center in Florida.

When the Apollo program concluded in the early 1970s, NASA turned the hardware that remained over to the National Air and Space Museum. Included were enough flight-ready or ground-test stages—approximately 645 tons of hardware—to assemble three Saturn V rockets. For some 20 years, the 363-foot launch vehicles have remained on outdoor display at or near NASA centers in Florida, Texas, and Alabama (see "The Others," p. 33). But while they've amazed millions, the rockets have fared poorly in their high-humidity environments.

During a five-month period last winter and spring, however, the Florida Saturn V was given a $1.7 million restoration—in funds privately raised by Kennedy's visitors' center—to prepare it for installation in a new facility built in its honor. A small team of Museum specialists, ourselves included, coordinated this sometimes grueling, often enthralling task: the restoration of the largest artifact in the Museum's inventory.

The three-stage Saturn V has long been associated with superlatives. Built to send 100,000 pounds of payload to the moon, it is the largest rocket ever successfully flown. The five enormous Rocketdyne F-1 engines that powered its first stage are the most powerful single-chamber engines ever built. Producing 1.5 million pounds of thrust apiece, they consumed some 2,300 tons of fuel, which was carried in tanks with a total capacity of 561,000 gallons. All this for the rocket's first 2.7 minutes of flight.

Of the 15 flightworthy Saturn Vs built, 13 were actually flown: One, in a two-stage configuration, launched the United States' first space station, Skylab, in May 1973. The remaining 12 were used in Apollo missions. Ten of these were manned; six resulted in landings on the moon.

The rocket was not built to endure the stresses of exposure on Earth, however. Twenty years of serving as a prominent landmark and popular tourist attraction at Kennedy had taken its toll. On closer inspection, the rocket's deterioration was far worse than originally thought. To keep the launch vehicle as light as possible—affording more weight to its payload, the Apollo spacecraft—the Saturn's skin was manufactured mostly of thin-gauge aluminum. Unfortunately, aluminum corrodes readily in salt air. Explains chemist Bayne Rector of the four-man Museum team, "When aluminum corrodes, it exfoliates into brittle layers that easily flake off, like pages in a decaying old book."

Apart from exfoliation, there were gaping tears, rusted rivets, frayed wire, and fungi and other plant growths. The rocket was also littered with innumerable red berries and small fish bones brought in by blackbirds called grackles, which had made the Saturn their home.

The first step was to house all but the oversized first stage in a cavernous, 20,000-square-foot, air-supported tent to protect the work and provide a controlled environment. (The first stage was later tented alone.) Next, the restoration crew power-washed the Saturn and its spacecraft with high-pressure

BERNIE HUNT

streams of water. Applied at pressures of up to 3,000 pounds per square inch, depending on the fragility of the material to be sprayed, 50,000 gallons of water were required for the first washing alone. "The power-washing got out a lot of dirt, bird droppings, bird nests, and other debris," says Rumanian-born Nick Bolea, a cheerful figure whose unofficial duties included serving as the crew's wildlife expert. Birds, turtles, opossums—even an alligator he named George—were frequent visitors to the site. Power-washing also produced a mysterious purple liquid—runoff, as it turned out, from the berries that had once served as food for the Saturn's former inhabitants.

FRANK WINTER (2)

Before the restoration started, a team from the National Air and Space Museum visited the Saturn to assess its condition. Above, Al Bachmeier inspects the launch escape system's tower. Its nose cone (left) later proved close quarters for a worker repairing the metal.

And the process took care of another problem: mildew. Almost a third of the rocket had a greenish hue, which the crew tackled by adding about 120 gallons of disinfectant to the water. The green was so pronounced on the first stage that Nick was able to write the name of his employer, "Thomarios"—an Ohio-based painting company and the job's chief contractor—in five-foot letters with his spray wand.

The rocket had been repainted several times while on display, and in places it had eight layers of paint. To remove it Thomarios' experts used a combination of two techniques. A device known as an ARMEX machine, which operates with a deafening screech, blasted away old paint and light corrosion with fine grades of ordinary baking soda. Its great advantage for this job was that it could strip paint without etching the metal. But while the ARMEX

RAY YOST

Two enormous propellant tanks dwarf workers patching metal inside stage one (left). Many aspects of the restoration were daunting, from the amount of corrosion that needed repair (below) to the area of the vehicle that needed paint (bottom).

worked beautifully on loose paint, it failed to remove well-adhered paint and corrosion. That job fell to a slightly coarser abrasive made from a volcanic sand.

This critical phase occasionally revealed unpleasant surprises. Prior to treating the first stage, a worker had made a knife hole in the 3/16-inch-thick aluminum to test its corrosion depth. The abrasive blasting revealed massive corrosion, however, and when the area was finished the hole had become large enough for three men to stand in.

Fortunately, this level of deterioration wasn't common. There were other holes to repair, "but overall the rocket was structurally sound," says John Lilly, a burly but gentle man known on the site for being able to fix anything. "The second stage was the one that depressed me."

Workers repaired the aft end of stage two by encasing the skeleton-like ribs, or "stringers," with new metal, reinforcing the section, and returning it to its original appearance while leaving the deteriorated material in place. (The work on the Saturn V was never intended to be more than a partial restoration. In a full restoration, every piece would have been removed and completely restored; a museum conservator would be apt to term our effort a "stabilization process.")

Many of the smaller holes on stage two were in the polyurethane foam sprayed on top of the aluminum to prevent the pre-launch evaporation, or "boil off," of the supercooled liquid hydrogen carried in one of the stage's two immense propellant tanks. Since the foam is relatively soft, birds had pecked holes in it, just as woodpeckers had recently pecked into the insulation on the space shuttle's external tank. When it rained, water got between the insulation and the aluminum. As it evaporated, the trapped water vapor caused blisters to form in the insulation.

There were almost 20 blisters, and they were troublesome to repair. First, each had to be surgically cut out with a knife. Then the space was cleaned and filled with an automotive-type body filler. When the filler dried, it was sanded down to original fuselage contours.

It was painstaking work, and the huge tent was, as Lilly put it, "a nasty place" to be in. Baking soda dust from the ARMEX machines permeated the stiflingly humid atmosphere, often clogging electrical machinery and causing breakdowns. Sweat trickled down workers' faces as hammers pounded, grinders buzzed, pneumatic guns popped, compressed air hissed, and fans constantly throbbed to keep the balloon-like building inflated.

BERNIE HUNT

It was little better outside in the blazing Florida sun, where plasterer Mike Ciocca made more than 80 duplicate heat shield panels for the back of stage one. The originals, which contained asbestos, had been removed earlier to comply with

To accelerate the Saturn to 15,750 mph, the second stage's five J-2 engines had to work for only six minutes. Restoring the J-2s took considerably longer, as these workers cleaning fittings could attest.

The Others

Along with the recently restored Saturn V at Kennedy Space Center, two other moon rockets survive, both titled to the National Air and Space Museum. The Saturn V Dynamic Test Vehicle, which had been built to test the effects of the vibration of its mighty engines on the entire launch vehicle, is on display at the Alabama Space and Rocket Center, adjacent to NASA's Marshall Space Flight Center in Huntsville, Alabama.

The Johnson Space Center in Houston, Texas, is home to the third Saturn V. Two of its stages—the first and the third—are from the vehicle originally intended for the cancelled Apollo 18 mission. Apollo 18's second stage is on the KSC vehicle; that on the JSC rocket is from the backup vehicle for the Skylab launch.

Both Saturn Vs have been displayed outdoors for approximately the same amount of time as the KSC rocket, but no plans or funding are in place at present for similar restorations.

Shrink-wrapping, which was applied to protect the rocket during the move to its airy new home, proved a canvas too tempting to resist: Just before the move, a "happy face" mysteriously appeared on the back of the lunar module housing. Below, graphic artist Gary Hagen adds some essential elements to stage one.

RAY YOST

Environmental Protection Agency standards. Because each had had a different shape, all 80 replacements—made of plywood, Styrofoam, nylon mesh, and synthetic stucco—had to be crafted individually.

Meanwhile, we on the Museum team were busy with some detective work. The paperwork in the Museum's archives about this vehicle was thin, and since we knew its stages had different origins, we wanted to use this time to verify their identities.

Our records indicated, for example, that the command module was one known as BP-30, meaning that it was one of the boilerplate versions used for ground tests. Confirming that, however, required climbing over the large, monkey-bar-like launch escape system tower extending from the module and peering into the module's newly opened hatch nearly upside down. By luck, a manufacturer's identification plate was close at hand—one of the few that was found on the launch vehicle—proving that this component really was what we had thought it was.

Sometimes we found discrepancies. The Museum's records indicated the third stage had been a ground-test stand-in for the Skylab workshop. But Kennedy documents discovered on our last visit to the site showed that this stage was flightworthy. Possibly at one time intended for the canceled Apollo 19 mission, it was considerably different from what we had believed it was.

Once the vehicle was painted and the ends of the stages tightly shrink-wrapped for shipping, the rocket was ready to make the move to its new home. The second and third stages went first, and the two-mile trip from outside Kennedy's monolithic Vehicle Assembly Building to the new Apollo/Saturn V Center was uneventful. Moving the first stage—138 feet long, 33 feet in diameter, and weighing 470 tons—was a different matter. Perhaps we shouldn't have been surprised: After all, the stage was so huge and heavy that it originally had to be transported to Cape Kennedy by barge. On this trip, the historic powerhouse had gone only a few yards when it was faced with a seemingly insurmountable obstacle: a six-inch-high curb.

Loaded on a 112-wheel hydraulic transporter, the stage seemed to be going

nowhere. The tow vehicle's mighty 600-horsepower engine struggled to muster enough energy to lift the colossus over the curb and onto the road. The stage refused to budge. The riggers placed logs of wood inside the curb to improve traction and create a ramp to ease it over. No luck. By now, curiosity seekers were losing their patience and thinning out.

The riggers brought in another heavy-duty truck, this one with a 400-hp engine. The two trucks were linked by cable, and an enormous concrete block was placed in the first vehicle to improve its traction. The double-truck convoy heaved until finally the giant stage edged over the barrier. The trip over the curb had taken two hours; the entire two-mile journey took 10.

Finally the stage was parked in the unfinished framework of the 450- by 100-foot building, joined by exhibits of a flight-ready Apollo Command Module, a Lunar Excursion Module, and a circular Saturn V Instrument Unit. Originally positioned atop the third stage, the unit contained the vehicle's navigation and guidance equipment.

The Apollo/Saturn V Center, which opens to the public December 5, will also feature an authentic reconstruction of a 1960s firing room where visitors can experience an Earth-rumbling Saturn V launch, a theater recreating the sensations of the first lunar landing, Apollo artifacts such as a moonrock and a spacesuit, and a gallery of interactive displays devoted to NASA's plans for the future.

But its centerpiece is the Saturn V, horizontally mounted on tall poles with its stages separated for visitors to inspect. As they look out from the striking metal and glass Apollo/Saturn V Center, visitors can also see the Banana River and beyond that, the launch pads. Today they service space shuttles, but a quarter of a century ago they were the dominion of Saturn Vs, poised at the start of their incomparable journeys.

Moving the Saturn on Earth has always been a challenge, and its most recent move—especially that of the first stage (bottom)—was no exception. When it pointed straight up, however, the rocket traveled with grace.

NASA (2)

VIETNAM MEMOIR

Escape to U Taphao

One way out of Saigon was on a Marine helicopter from the roof of the U.S. Embassy. The other was with a South Vietnamese Air Force pilot making a break for Thailand.

by Ralph Wetterhahn

Illustrations by Ken Dallison

When the North Vietnamese attacked Tan Son Nhut Air Base, pilots took fighters, like the A-37 Dragonfly, and transports to fly themselves and their countrymen to safety.

Henry Le remembers everything about his last morning in Vietnam. Then a 22-year-old second lieutenant in the South Vietnamese Air Force, he had landed at Tan Son Nhut Air Base outside Saigon the day before, too low on fuel to make it back to his home base at Can Tho. At 4 a.m. on April 29, he was awakened by the concussion of rocket explosions. "I was in a bunk on the second floor of the barracks," he recalls. "I sat up and for a few moments tried to understand where I was."

Today Le is a lieutenant commander in the U.S. Naval Reserve, having flown S-3 Vikings on active duty patrolling for

submarines in Subic Bay and A-6 Intruders in the Persian Gulf. On that morning 21 years ago, he was a newly trained A-37 pilot with only a handful of combat sorties behind him. The Cessna A-37 Dragonfly was a small but capable attack bomber equipped with a 7.62-mm gun and able to carry as many as six 500-pound bombs under its wings. Le and his fellow A-37 pilots had been supporting ground troops and trying, mostly unsuccessfully, to slow the Northern assault that by then had tanks and artillery moving in a solid column down Highway 1 toward the capital. But not until the rockets began raining down on the suburbs of Saigon that morning did he know the war was lost.

Most of the Americans involved in the conflict remember seeing the end coming long before Saigon fell. One of them, Air Force Brigadier General Harry "Heinie" Aderholt, commanded the U.S. military's assistance and advisory operations in Thailand (MACTHAI). Aderholt had begun his career in southeast Asia in 1960—as the senior air officer in covert operations in Laos—and spent most of the next 15 years there. He trained Laotian Hmong guerrilla units for incursions into Tibet and is today a leader of a volunteer organization that helps settle Hmong refugees in the United States. In the war stories he tells, Aderholt is a rascal who made general, and he still has a rascal's glint in his eye. He does not suppress his distaste for past U.S. policy in southeast Asia, and recommends one history of that period with this endorsement: "It'll show you what bastards we are. How we always desert our allies."

Aderholt was chief advisor to the Royal Air Force in Thailand before going to the MACTHAI in 1973. By 1974 he had already begun to worry about Vietnam's neighbors—Thailand, Laos, Cambodia—all of the small, poor countries vulnerable to what would soon be an enormous air power. For as the United States drew down its forces in South Vietnam, it pumped up that country's arsenal. By the end of March 1973, in accordance with the agreement signed that January in Paris, only 50 U.S. military officers and 159 Marine guards remained in the country. But the Republic of Vietnam Air Force had grown to the fourth largest in the world, from 482 aircraft in 1969 to 2,276 in 1973. Aderholt saw that the ultimate benefactors of this military aid would be the North Vietnamese, and he wanted to reclaim as many airplanes as he could for the United States and its allies.

Aderholt was particularly concerned about 150 Northrop F-5 Freedom Fighters, 40 of which were E and F models that had just come off the production line, and 78 A-37s. The F-5s were Mach-1.6 fighter-interceptors that, with the capacity to carry 6,200 pounds of rockets, bombs, or missiles, doubled as attack aircraft; they especially would pose a significant threat to Thailand, a country with a far smaller, far less modern air force. In the beginning of 1975, Aderholt sought permission from the U.S. Embassy in Saigon to begin bringing aircraft out of Vietnam. He had no authority himself to remove assets that had been loaned under the Military Assistance Program. After U.S. forces withdrew from Vietnam in 1973, military decisions there were made by the state department.

"I presented a plan to [Graham A. Martin, U.S. ambassador to Vietnam] for the evacuation of all U.S. supplied aircraft" in the early months of 1975, Aderholt says. "But the plan was scrapped. Martin said he would entertain 'no defeatist attitude.' "

On March 10, 1975, General Van Tien Dung, North Vietnamese commander in the South, attacked Ban Me Thuot, a strategic city in the central highlands of South Vietnam, beginning the last offensive of the war. Seven weeks later his victorious army marched through the gates of Saigon's presidential palace. In the interim, 933 VNAF aircraft fell undamaged into enemy hands. But not Henry Le's A-37.

When the second salvo of rockets lit up the night, Le leapt from his cot, jumped into his flightsuit, and rode on his motorcycle to the main gate of the air base. "I grabbed a packet of documents including flight training certificates—all important for starting over in a new country," he says.

The base guards had orders to keep all personnel outside until the attack was over. Frustrated, Le listened to details of the ongoing battle via a tactical radio in the guard shack. He heard a pilot call the tower.

The pilot was orbiting in an AC-119 gunship over the base at 7,000 feet, desperately trying to locate the source of the rocket fire. He requested permission to drop to 4,000 feet to get a better fix on the enemy location. Le could hear the roar of the AC-119 but could not see the aircraft because the pilot was operating without lights. Le remembers that as dawn turned the sky gray, the AC-119, a bulky, black transport with guns mounted along the port side of the fuselage, swept into view and laid down a sheet of 7.62-mm fire on the enemy position. "It was the final act of bravery I saw in the battle to save my country," Le says.

As Le watched, an SA-7 shoulder-fired missile sailed wide of the attacking gunship. Then a second missile appeared, its exhaust tracing a crooked line as the SA-7 adjusted its course to follow its target. It struck the airplane's right engine. As the airplane dove, the right wing caught fire. A crewman bailed out but his chute got tangled in the tail as the aircraft started to break apart. Flames billowed behind the gunship. It rolled inverted and made three-quarters of a turn before slamming into the ground.

The guards, who had also witnessed the crash, now allowed Le onto the field. Inside the gate, pilots rated in all types of aircraft were searching for airplanes they could fly. There had been no briefings or plans for retreat. Just two weeks earlier in a radio address to the nation, General Nguyen Cao Ky, former South Vietnamese prime minister, had urged his forces to stay and fight, vowing to fight to the death himself. That morning on the base Le watched Ky board a helicopter that flew east toward the U.S. fleet.

The pilots gathered to discuss their

General Heinie Aderholt (above) knew he'd have to devise ways to get U.S.-supplied aircraft back to the states. He had Captain Roger Youngblood (right) hide A-1 Skyraiders at a Thai air base that had once supported CIA operations.

People frantic to escape from Saigon overloaded aircraft. One F-5 arrived in U Taphao with three fliers crammed into the cockpit. A C-47 brought 100 passengers. Colonel Harold Austin (below) was responsible for managing the flood of aircraft and refugees.

options. Conversation was tense and chaotic, but the choice was simple: Evacuate all flyable aircraft or blow them up.

Over the previous two weeks, Le and his friends had discussed the destinations that would be available to them if the worst happened and Saigon fell. They could attempt to fly to U Taphao Air Base in Thailand, some 350 miles to the northwest, or, if they had enough fuel, to Singapore, 580 miles southwest. Another option was to head for the U.S. Navy carrier fleet off the coast to land aboard ship or ditch. Long-range airplanes, like C-130s or -123s, could try to make it to Subic Bay in the Philippines, 785 miles to the east. A final option was to simply take off and eject wherever fuel ran out.

At 9:45 a.m., the base intelligence unit broadcast a warning that a massive rocket attack was about to begin. Pilots and crew members ran for their aircraft as VIPs loaded staff cars in a mad dash to escape. At 10 a.m., rocket salvos began rolling across the base.

"Friends got together with friends," recalls Le. "All of us ran, checking aircraft to see if we could find one that was flyable." Le found an A-37 with fuel, and he, a pilot friend, and a maintenance crewman crammed themselves into the two-seater. That eliminated the ejection option for Le's friend and the maintenance crewman. "I promised them I would ride the airplane into the ground with them if necessary," Le says.

Le started the engines and taxied. "It was a mess," he says. "No one was manning the tower. Aircraft jockeyed for position, trying to get to the runway and into the air before being damaged by rockets." An Aim-9 missile lay in the center of Le's path. Empty fuel tanks littered the area.

Inside the A-37, Le listened on the tower frequency, awash with confused and panicky calls as pilots asked for directions that would never come. As he waited for his chance to take off, Le watched the chaos around him.

"In the distance, a twin-engine C-7 [Caribou] rolled down the runway. The pilot had forgotten to remove the control locks," Le recalls. "The plane never got airborne. Instead, it plowed into the overrun and burst into flames. People came crawling from the wreckage. Some ran, others limped back to the ramp looking for other aircraft to board."

Finally, Le took his turn on the runway. To the north, raging fires and towering columns of smoke marked ammunition dumps that were being blown up before the arrival of the Communist forces. Le added power, took off, and headed west.

Colonel Harold R. Austin, commander of the U.S. Air Force 635th Combat Support Group at U Taphao, was in some ways prepared for the problems he faced on the morning of April 29, 1975. During the U.S. involvement in the war, Strategic Air Command B-52s had been based at U Taphao for strikes against North Vietnam. Some 20 of the big bombers were still standing by, protected in three-sided revetments. To support the B-52 operations, SAC had installed a 12,000-foot runway and taxiways, a stroke of good fortune for the pilots who were now landing their airplanes on both ends of the runway without clearance.

But by 9 a.m. things at the flightline were already out of control. Helicopters settled onto the grass between the runway and taxiway. One landed amid the revetments. A C-47's landing gear collapsed on touchdown. The airplane, a military version of the DC-3 built to accommodate 30 troops, had carried 100 passengers out of Vietnam. The accident blocked the runway, but pilots con-

tinued their attempts to land.

"We got all the SAC airplanes on the ground as soon as we realized what was going on," Austin says today. "I had the tower broadcast [to arriving aircraft] on all available channels to be on the lookout for airplanes without radios.

"You have to understand we weren't fighting a big war," Austin says. "We were standing by to fight. So I had 6,000 people with not a whole lot to do. And everybody pitched in—SAC guys, MAC guys. I had excellent cooperation."

GIs in any vehicles available towed A-1s, C-47s, O-1 Bird Dogs, and all the smaller aircraft onto the grassy infield, making room for incoming jets and the larger transports. Others painted out VNAF markings. Under the extreme circumstances, aircraft were parked without chocks, their canopies left open. Maintenance crews de-armed the combat aircraft, stacking ammunition in piles along the parking ramp.

By the end of the day, 165 VNAF aircraft were at U Taphao, including 31 F-5s, 27 A-37 Dragonflys, nine C-130A Hercules transports, 45 UH-1 Bell helicopters, 16 C-47s, 11 A-1E and H Skyraiders, six C-7A Caribou transports, three AC-119 gunships, 14 Cessna U-17 Skywagons, three O-1 Bird Dogs, and a handful of civilian aircraft. The airplanes were crammed among 97 Cambodian aircraft that had arrived since April 12, when Phnom Penh fell.

In addition to trying to keep the runway clear and securing aircraft and weapons, Austin had to manage the flood of refugees. "Most of them were very emotional, hungry, and dehydrated," Austin recalls. "They were scared to death." Many had suffered horrible losses in addition to losing their homeland. Austin remembers one group in particular that had flown in on a C-130. Passengers had been boarding the aircraft at the Tan Son Nhut base when rockets started to fall. The engines were already running, and the pilot began to taxi. The copilot's wife had been leaning outside, helping load passengers at the front entryway. As the plane lurched forward, she fell. The left main gear rolled over her, crushing the woman. No one told the copilot until the aircraft landed in Thailand.

Austin had to get the refugees fed and made as comfortable as he could. He kept the families together and set up temporary living quarters for them in the hangar area and in the airmen's annex. He sent the single males to the U.S. Navy maintenance facilities, where tents were being set up for additional shelter.

Henry Le was one of the refugees who spent the night in a tent at U Taphao. He had landed with his passengers at about midday, when the ramp was overflowing, and was shocked by the number of airplanes already on the ground. As he was taxiing in, several GIs stopped him, painted over the insignia on his A-37, then waved him on.

As Austin was organizing food and shelter for the refugees, he was also conferring with foreign service officers at the U.S. Embassy in Thailand. "The Thais had made it clear that they wanted the Vietnamese nationals out of the country in no uncertain terms," Austin says.

"The Thais were afraid that the Vietnamese would take vengeance on them," says Aderholt. "Besides, they had been there before. During the exodus in 1954,

U Taphao had a 12,000-foot runway and generous taxiways, but even these were overwhelmed by the arrivals.

northeast Thailand had many Vietnamese infiltrate and become homesteaders. They were still there. So the Thais had no love for the Vietnamese."

Austin communicated the dilemma to his headquarters at the Pacific Air Force in Hawaii. Twenty C-141s were ordered to U Taphao the next day to airlift the Vietnamese, Henry Le among them, to Guam, where a tent city had been erected to receive them. But as the first transports arrived, Austin faced a new problem.

Sixty-five of the Vietnamese arrivals, all from one C-130, wanted to go back to Vietnam. Led by 27-year-old Second Lieutenant Cao Van Li, these VNAF personnel had not realized they were leaving the country when the aircraft took off from Saigon. They had left their families in Vietnam, and now they threatened suicide if their request to return was denied. "They were all youngsters," says Austin. "We told them we were sending them to Guam. They'd never heard of Guam."

Austin enlisted the help of a VNAF colonel, who pointed out to the men that they would almost certainly be shot if they returned. An American chaplain also helped with the negotiations. "He worked his tail off," says Austin. And as the C-141s came and went, all but 13 Vietnamese agreed to leave for Guam. With 3,900 refugees already airlifted out, Austin continued trying to coax the last group aboard. "U.S. Embassy and Air Force interpreters informed the refugees that under Thai law they could be categorized as illegal immigrants and as such would be jailed and shot," Austin says, but the Vietnamese were adamant. Austin's medical personnel suggested sedating the remaining 13, a practice they had used before when dealing with medical evacuees who were apprehensive or whose condition required immobility during travel. With the lone C-141 holding on the ramp for departure and the Thais threatening to put the rebels on by force, Austin approved the sedation.

The first Vietnamese to be sedated was carried into the medical trailer. The remaining 12 hesitated but did not resist. Austin directed four Air Force security policemen and a male nurse to accompany the aircraft.

When the aircraft landed at Guam, Lieutenant Cao Van Li protested his treatment to officials there. "I am not a Communist," he said, "but I want to go home. My family is there. They need me." The press picked up the story. Suddenly Austin found himself the focus of an international incident that eventually resulted in his removal as commander of the 635th. "I'd make the same decision today," Austin says.

A few days before the exodus from Saigon, Aderholt had sent Air Force Captain Roger L. Youngblood to Trat Field on the Thai border with Cambodia. Flying a Royal Thai Air Force AU-23 (a derivative of the Pilatus PC-6 Turbo-Porter that could handle the short runway at Trat), Youngblood orbited in the area with a Vietnamese co-pilot. The co-pilot stayed on the radio giving the tower frequency for U Taphao and trying to direct pilots to land there. Not

all of the pilots made it.

On the night of April 29, Aderholt, who had advisors all over Thailand, started receiving information about airplanes that had landed in fields, on roads, in any clearing the pilots could find. An A-37 that had landed on the highway near Korat Air Base, north of Bangkok, was sitting near a school. The pilot had taxied off the road and into a schoolyard before shutting down. The airplane still carried bombs under its wings. Aderholt dispatched an Air Force captain from Udorn to fly the A-37 back to that base.

The reports continued to come in, and on May 1 Aderholt ordered U.S. Army helicopters detailed to MACTHAI to ferry pilots and 55-gallon drums of jet fuel to locations in Thailand and Cambodia where airplanes and helicopters had landed. Youngblood flew back to Trat with former forward air controller Briggs Dogood to make one of the trickier recoveries.

"We went by jeep to a nearby rice paddy where an O-1 was stranded on a cart path with barely a foot clearance on either side of the landing gear," Youngblood recalls. "Dogood paced off the length of the path, put some gas from a tanker truck into the plane. Then he got in and in a cloud of dust flew the O-1 off the cart path."

When it became clear to Aderholt that the North Vietnamese were going to claim the airplanes and helicopters that had escaped into Thailand, Youngblood also flew aircraft out of U Taphao. Aderholt learned that the Hanoi government's first move would be to send a delegation to Thailand to inventory the VNAF aircraft. The Thai government, intimidated by Hanoi, ordered the aircraft impounded. "The aircraft were Military Assistance Program assets and as such still belonged to the U.S. government," says Aderholt, but he wasn't sure that he could count on the Thais to see it that way. He decided to get as many of the aircraft as he could to the United States fast.

Air Force HH-53 helicopters turned out to be unequal to the job of ferrying F-5s to an aircraft carrier for transport to Guam. One helicopter dropped a fighter onto a dock; another dropped one into the sea.

Aderholt first gave five F-5As to the air chief marshal of the Royal Thai Air Force to get the Thai military on his side. He had no authority to do so; the U.S. Embassy, in negotiation with the Thais and the North Vietnamese, was responsible for the final disposition of the aircraft. But, Aderholt knew, it would be difficult for the state department to take back the gift.

Aderholt learned from Pacific Command in Hawaii that the USS *Midway* was on its way to a Royal Thai Navy Base near U Taphao, to offload U.S. HH-53 helicopters that had taken part in the evacuation of Saigon. Says Aderholt, "The *Midway* was given a new mission: Load the most valuable VNAF aircraft currently at U Taphao."

On May 5 the aircraft carrier pulled into port, and Austin hurriedly began the transport of jet aircraft by helicopter to its deck. Two F-5s fell from the helicopter slings: One dropped 25 feet onto the dock and the other into the water. The remaining aircraft were then moved overland by truck to the port at Sattahip, and no more were lost.

Loading only the most valuable aircraft aboard the *Midway* meant, of course, that older combat aircraft, like the A-1 Skyraiders, would be left behind. These propeller-driven aircraft had proven effective in close-air-support and rescue operations, and Aderholt was not about to let them fall into Vietnamese hands. With the blessing of the Thai military, Aderholt ordered Youngblood and Major Jack W. Drummond, both pilots who had flown Skyraiders years earlier, to U Taphao to fly the A-1s to a "less conspicuous location."

"Start, taxi, and run up were accomplished and the thrill of sitting behind the single 3350 [Pratt & Whitney engine] came rushing back," wrote Drummond of the incident in a recent A-1 Skyraider Association newsletter. "Takeoff was no sweat. Both of us felt that we had probably made the best landings of our A-1 careers!"

They delivered the airplanes to Ta Khli Air Base in central Thailand and parked them out of sight in a hangar. (Aderholt was familiar with the base because he had worked with the CIA there to send U-2s on missions over China.) The two pilots returned to U Taphao and brought another pair of A-1s to Ta Khli. When the U.S. Embassy in Thailand found out about the F-5s that were given to the Thai air force and the movement of A-1s, Drummond and Youngblood were returned to their regular duties, and the remaining A-1s stayed at U Taphao.

While the U.S., Hanoi, and Thai governments arm wrestled, the *Midway* and several other Seventh Fleet ships slipped port loaded with 142 VNAF aircraft bound for Guam. At least one

C-123K also made it out of Thailand. Today tail number 54-00592 is at Avra Valley Airport in Marana, Arizona. No one remembers the details of how it came to be there.

Aderholt retired from the Air Force in 1976, but he stayed in Thailand for four more years—long enough to arrange transport home for the four A-1s he had sent to Ta Khli. He says today that he knew those aircraft had become rare in the United States and he wanted to make sure a few were preserved.

Aderholt rented tractors to pull the airplanes from Ta Khli to the Chao Prya River. He had them loaded on four barges brought up from Bangkok, which immediately got mired in shallows. Aderholt bribed the keeper of the Chainat Dam with 20,000 baht ($1,000 at the time) to open the flood gates. The barges floated down river to the port, and the aircraft were loaded on a ship. Later, warbird collector Dave Tallichet brought them to Los Angeles and stored them at Orange County Airport until 1986. Tallichet still flies one of the Skyraiders out of Chino Field in California. Another is on display at the Santa Monica Museum of Flight in California.

No aircraft were sent back to Vietnam by the Thais. The *Midway* delivered its load of 101 VNAF aircraft to Guam, making it possible for 21 F-5Es to come back to the States through McClellan Air Force Base in California. Each had logged only 64 to 115 hours flying time. Most of them found their way to Williams Air Force Base in Arizona, where they were used to train foreign pilots. Of those, five were moved from Williams to Nellis Air Force Base in Nevada in 1977. For the next 12 years, the F-5Es were used in the 57th Wing Aggressor Squadrons to demonstrate Soviet Bloc tactics to U.S. pilots (see "Grounded: The Aggressor Squadrons," Feb./Mar. 1994).

In 1988 and 1989, the F-5s were sold to Brazil and Honduras; some spent a brief period with the U.S. Navy. But the U.S. pilots they had helped train went on to establish a 41:0 kill ratio against Soviet-trained Iraqis in the skies over Baghdad in 1991. No small part of that triumph can be attributed to the efforts of the VNAF pilots. Many of the airplanes they flew out of Vietnam are still flying missions around the world. Their own air force ceased to exist on April 30, 1975. Its official history covered 20 years, during which its pilots knew not a single moment of peace.

Almost 4,000 Vietnamese fled to U Taphao that April. Most of them eventually entered the United States through a refugee camp in Arkansas.

THE ROTARY CUP

The World Helicopter Championships is a quirky blend of rodeo, auto rally, and company picnic.

by Preston Lerner

Photographs by Michael Melford

Some of the championship's events looked a little goofy but reflected critical flying skills: Dropping a "skittle," or bowling pin, through a 16-inch-square cutout within 20 seconds tested chopper pilots' abilities to carry out such missions as dropping rescue gear to downed pilots.

By late afternoon on the first day of the World Helicopter Championships, the giant tent set up at the far end of McNary Field resembled nothing so much as a World War III POW detention area. Dozens of pilots in flightsuits color-coded by nation lounged at long tables, listlessly trading stories in French, German, Italian, Russian, Japanese, Greek, and several varieties of English. Just outside, fliers quietly smoked cigarettes under the watchful eyes of khaki-clad soldiers. Security was so tight that no one was allowed to go to the bathroom without a military escort. "Now I remember why I left the Army," one aviator muttered.

Every so often, the torpor was broken when a new crew entered the steamy, airless tent, having just finished the long-navigation event of the championship. In the "long nav," crews were given coordinates for an intricate route and had only five minutes to study them before taking off. And they had to navigate the old-fashioned way: no GPS; just compasses, clocks, and airspeed indicators. Because prior knowledge of the course would have been an enormous advantage, each crew, after finishing its run, was spirited under guard to the quarantine tent, where it had to wait. And wait. And wait some more.

By mid-afternoon, the silly season was in full swing. One group of fliers went stir-crazy and started climbing the tent's center pole. Another formed a human pyramid. Meanwhile, a U.S. Coast Guard crew patiently fielded dumb questions from the press. To wit: What kind of people choose to fly helicopters rather than fixed-wing aircraft?

"The smart ones," pilot Wes Trull said.

"The good-looking ones," added Tim Fitzpatrick, who manned the controls of the crew's bright orange HH-65 Dauphin while Trull served as navigator.

Their flight mechanic, Tom Kimura, closed his paperback novel and laid his pipe on the table. "You want to know why people fly helicopters?" he said. "Because they flunked driver's ed."

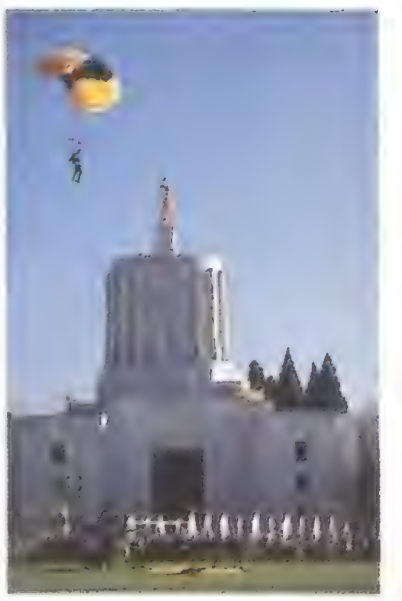
Helicopters get no respect. They don't look very sexy, and they make that annoying *whop-whop-whop-whop* sound. There's no great creation myth for rotary-wing aircraft, no celebrated conquest of the Atlantic, no electrifying adventures on the cusp of outer space. But once every two or three years, chopper pilots get a chance to do a star turn. The occasion is the World Helicopter Championships. Think of it as a local airshow with Olympic aspirations.

Last August, 50 crews converged on Salem, Oregon, for the ninth championship held since 1971. The crews competed in four events designed to test the skills required for such real-life helicopter duties as controlling sling-loads at construction sites, lowering rescue gear to downed pilots, dropping water onto fires, and flying search-and-rescue missions. For each event, crews competed for gold, silver, and bronze medals, with the overall world championship going to the crew with the highest aggregate score in all four events. Also being contested was an overall team championship, which was based on the total score of the top three crews from each country.

From the start, most agreed that top-team honors would probably go to either the Russians, who'd won the last two championships, or the 12-crew American team, which had dominated the event in the 1980s. But Germany, Great Britain, France, Japan, and South Africa all sent multi-crew teams intent on going for the bronze. Rounding out the entries were single crews from Greece, Canada, Italy, Monaco, and Puerto Rico.

The easiest way to handicap the field was to examine the helicopters. The Americans had their own: In addition to the Coast Guard Dauphin, they had brought Bell OH-58s—two-seat Army scout and attack helicopters—and Bell 206 LongRangers, stretched versions of the JetRanger general-purpose chopper. The Canadian Royal Air Force crew flew their Bell 412 over the border. And the Russians had shipped over a trio of venerable Mil Mi-2s, light helicopters used by Eastern bloc countries for both civil and military applications since the early 1960s.

The crews from other nations made do with whatever they could scrounge up. The Royal Air Force's David Jones and Stan Laver



Parachute drops, balloon rallies, and assorted flying demonstrations all kept the crowd engaged. Even though some of the competitive events were less than riveting, there was usually something happening everywhere you looked.

got their first minutes in their rented chopper when they started their long-nav run. "We didn't even know if we were going to have a helicopter until three hours after the competition began. It's not exactly the way we planned it," Jones said with characteristically British understatement. For the most part, crews from the United Kingdom, Greece, South Africa, and Japan made do with Robinson R22 light helicopters.

The field was very much a mixed bag. Military pilots squared off against civilians, full-time professionals against fair-weather dilettantes. For some, the competition was deadly serious, while others seemed to consider the championship a working holiday. Tellingly, these pilots kept complaining that they didn't have enough time to socialize. Some hadn't done much in the way of preparation. "We didn't start practicing until two days before the event," said Japan's Kengo Mori. "And instead of flying with a navigator, I'm flying with a maintenance mechanic."

Realistically, only a handful of pilots had a shot at a medal. With only 100 hours of flight time in his log, Italian national champion Aldo Ferruzzi wasn't one of them. "When I read in the rules that there is a prize for pilots with less than 250 hours, I say, 'This is for us!' " he said with a laugh after scoring zero out of a possible 200 points on the long-navigation event.

The only common denominator among the competitors seemed to be a shared appreciation for the skills a pilot needs to bend a helicopter to his or her will—a task that British pilot Caroline Gough-Cooper likened to "balancing a marble on top of a basketball." While many of the fliers also held fixed-wing licenses—several, in fact, were airline pilots—all agreed that nothing beat the challenge of rotary-wing flight. "Once you take off in an airplane and trim up the controls, it will basically fly itself. A helicopter won't," said Jeff Linscott of the U.S. team. "There are a lot of things in life that don't require your full concentration. A lot of the time, even when you're flying an airplane, your mind can wander and you can still be okay. But in a helicopter, 100 percent of your mind has to be on flying 100 percent of the time."

The long nav proved to be the trickiest of the four events. As the crews navigated their way along the course, they had to spot 10 symbols hidden on the ground and "bomb" two targets with bean bags. The tasks had to be completed at a minimum altitude and speed and within a prescribed period of time, all varying with helicopter model. "You wouldn't believe the pressure," said Sheila Sorensen, navigator on the sole female civilian crew of the U.S. contingent. "My voice went up eight octaves, and I was sweating so much it was like someone had turned on a faucet." The event defeated even the defending world champions; Tatjana Stekolnikova and Lioudmilla Korneva—two

The slalom event required each crew to haul a water-filled bucket through 10 gates. The bucket had holes in its sides, and the judges determined penalties by measuring how much water sloshed out the holes.

self-possessed, chain-smoking Russian women—lost track of the time while studying their map before the start of the long-nav. When they exceeded their five minutes of planning time, they were eliminated from the running for the overall title literally before getting off the ground. Thirteen other crews also carded goose eggs in the event, though not quite as abruptly.

In the timed arrival, on Day Two, pilots had to navigate a short course in a specified time based on the cruising speed of their helicopters. Each crew started with 200 points, and for each second they missed their assigned arrival time by, a point was deducted. Then they had another 60 seconds to complete a rectangular landing pattern, again with a one-point-per-second penalty in effect. Finally, each copilot had to lower a "skittle," or bowling pin, by a 23-foot rope through a 16-inch-square hole in a piece of angled plywood meant to represent the roof of a doghouse. Teams were dinged for every second more than 20 that it took them to get the bowling pin through the doghouse. And if they missed the doghouse altogether, no matter how well they did on the rest of the event, they scored a zero.

The doghouse portion brought the craft of the "chopper dudes"—Jeff Linscott's phrase—into sharp focus. While the copilot dangled out of the helicopter and shouted commands over the radio, the pilots made minute corrections in altitude and heading, yawing left, skidding right, bringing the skittle ever closer to the cutout. While Linscott and navigator Alden Andre breezed through in a championship-best 11.37 seconds, Sorensen and pilot Joann Stevens spent 67 agonizing seconds hovering over the doghouse before dropping their skittle. "Oh, those poor girls," Australian judge Gaby Kennard shouted, her words nearly drowned out by the roar of the Bell LongRanger overhead.

The Canadian air force crew was luckier. Navigator Wayne Timbury recalled: "I had 10 seconds of practice the night before, and the rotor wash was so strong that it just blew the skittle away, so we figured that we'd lose all our points on the doghouse. But Andre [Rioux, the pilot] did a great job flaring to bleed off speed. Then he turned sideways. The skittle took a big swing and I lost sight of it. The next time I saw it, it was over the hole so I let it go." Timbury laughed. "It was pure luck. We had a couple of beers to celebrate."

While the fliers were relaxing, the judges

Monaco's Jean-Paul Cavalier and Fabrice Papaizan (above) washed out in the long-nav event, as did 13 other crews, including Italy's Aldo Ferruzzi and Tiziano Sangiorgi, flying a Hughes 269C (below).

worked late into the night ruling on the numerous protests that had been filed over the scoring. So many had been filed, in fact, that the official results for the first two events weren't posted until nearly 24 hours after they were over. One American, whose protest was rejected, fumed: "The judges are completely arbitrary, inconsistent, and incompetent."

Yes, there were some communications problems, and yes, the let's-compare-stopwatches standard may have left something to be desired, but the judges, most of whom were helicopter pilots themselves, appeared to be doing their best. And it seemed churlish to complain too much about their performance, considering all the sun and noise and rotor wash they had to brave. (In the U.S. nationals, one judge was blown off her feet by the Coast Guard's Dauphin.)

The long delays and endless disputes increased the strain on the already-tense U.S. camp. The organizers were intent on wresting the world title back from the Russians, so to put together the strongest U.S. contingent possible, they had held flyoffs at McNary Field. Three of the 15 crews competing were cut just before the world championship. "Cutting those crews the day before the competition began was probably the most difficult thing I've ever done," said team captain and two-time national champion Jim Hutchens. The selection process left some of the competitors with bruised

The Russians' Mi-2s (above) weren't going to win any awards for gracefulness, but their design beautifully suited the demands of the competition.

The South Africans, whose uniforms could have earned them a "Spiffiest Dressers" award, placed third in the team competition.

feelings, and the crews who did make the cut had to compete knowing that they were flying only because some of their buddies had been relegated to the sidelines.

And the Americans' unhappiness only increased as the Russians pulled ahead in the team battle. Their Mils were homely, cumbersome beasts, with controls that looked like they belonged in a tank and engines that spewed black smoke. But they were better suited to the competition than the Americans' Bell OH-58s—more stable in high winds and better configured for the tasks that involved leaning out of the cockpit.

The Russians' slick competence was spotlighted on Day Three in the precision flight event, which required pilots to fly forward, sideways, and backward—and pirouette—along a narrow course while maintaining an altitude of about seven to 10 feet. It seemed as if every Russian could reach the prescribed altitude and simply stop, as if he'd hit a ceiling.

The general consensus—and not just among the Americans—was that the Russians ought to be good, considering how much time they'd spent practicing. But Sergei Debassov, a stocky, square-jawed man who looked like Central Casting's idea of a front-line Russian infantry commander, insisted through an interpreter: "We were extremely short on money and did not have a chance to train very much. I'd say we had a total of 30 hours for all four events."

Ending the competition with a flourish was the slalom, in which crews maneuvered a water-filled bucket slung out a door and through a series of 10 slalom-style gates, then climbed to 36 feet and set the bucket down—without spilling any water—on a bull's-eye. In this event, the Russians were simply untouchable. After watching a U.S. crew butcher the course, Jeff Johnson couldn't help feeling dismay as a Russian crew danced gracefully through the slalom. "It's like the gates aren't even there," he said. "They don't even slow down for them."

Although the results weren't released until the closing banquet, the awards were a foregone conclusion. Heath Niemi and Andy Fisher picked up the only U.S. gold medal—for the timed arrival. In the other three events, the golds went to the Russians. Debassov and Mikhail Kormagin won overall world championship. Another Russian crew came in second, while Jim Hutchens and Jeff Johnson placed a valiant third.

In the team competition, the Russians squeaked past the United States. But the biggest cheers were reserved for the South Africans, whose team won third place, serving as a reminder that this wasn't just a duel between Russia and the United States—it was the *World* Helicopter Championships. As a spectator event, it wasn't going to make anybody forget the NBA Finals. But if hot-shot flying was your bag, Salem was the place to be.

The competition officials had their hands full scoring events, ruling on protests, and acting as traffic cops.

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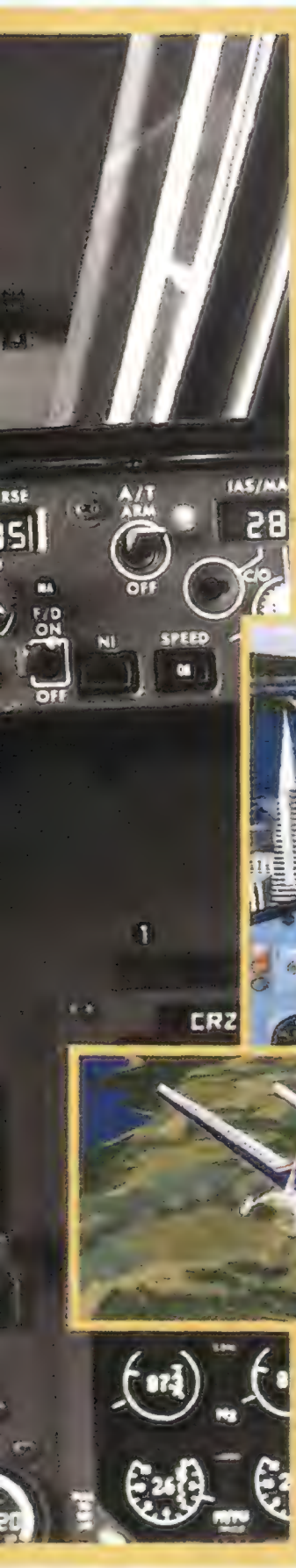

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The United States stood as the world's sole nuclear power for barely four years: from July 16, 1945, when the first A-bomb test was conducted in New Mexico, to August 29, 1949, when the Soviet Union detonated its own atomic bomb in Kazakhstan. During that time, the Pentagon, having identified the Russians as the next adversary, had no single vision of how to press its nuclear advantage. Some were ready to heed the warning of General Henry "Hap" Arnold, commander of the Army Air Forces in World War II, who as early as 1943 believed that "someday, not too far distant, there can come streaking out of somewhere some kind of a gadget with an explosive so powerful that one projectile will be able to wipe out completely the city of Washington." At war's end he urged that "we should be ready with a weapon of the general type of the German V-2 rocket, having greatly improved range and precision, and launched from great distances."

But no one knew how to build such a weapon, which would require very large rocket engines along with a guidance system of great accuracy. Such systems did not exist, even on drawing boards, and plenty of people were ready to dismiss Arnold's vision as fantasy. Vannevar Bush, who had directed the wartime Office of Scientific Research and Development, testified before the Senate in 1945: "I don't think anybody in the world knows how to do such a thing, and I feel confident it will not be done for a very long period of time to come. I think we can leave that out of our thinking."

The Army Air Forces decided to initiate a modest investigation of the propulsion and guidance technology needed for an advanced V-2. In the spring of 1946, the service funded a series of inexpensive studies at major aircraft companies for systems to deliver nuclear bombs. The first arms race had begun, and the major contenders would include the San Diego-based Consolidated Vultee Aircraft Corporation ("Convair" for short) and North American Aviation in Los Angeles.

Karel Bossart, a specialist in aircraft structures whom everyone called Charlie, landed the job of running Convair's missile study. Bossart had grown up in Belgium, earning a degree in mining engineering in 1925 before becoming a fellow at the Massachusetts Institute of Technology. That school introduced him to aeronautics, and he spent the war as an airplane man.

For the $1.9 million the Army Air Forces offered, Bossart's group proposed three projects, all aimed at building a missile with a range of 5,000 miles, roughly the distance between New York and Moscow. Design A would be a cruise missile, an unmanned jet aircraft that would fly horizontally within the atmosphere by relying on an advanced autopilot. Design B would be a short-range rocket, and Design C would take shape as an intercontinental ballistic missile. Propelled by the thrust of its rocket engines, an ICBM accelerates upward, following a trajectory that takes it well beyond the fringes of the atmosphere before reentering and falling toward its target.

Convair propulsion engineer Bill Lester nicknamed the three projects. He christened Missile A "the Teetotaler," because it was the only one of the three that would not be fueled with alcohol. He called Missile B "Old Fashioned," because it would resemble the V-2. Project C, the long-range rocket, would carry a nuclear warhead. Lester called it "Manhattan" after the atomic bomb project. The Army Air Forces, lacking Lester's sense of humor, designated the contract MX-774 and approved the construction of 10 missiles. "We were left alone, no boss coming around to tell us how to do it," Bossart later recalled.

Bossart designed the MX-774 by copying the shape of the 200-mile-range V-2; this allowed his aerodynamicists to use German wind tunnel data. He also needed a rocket engine, and he knew he would have to take whatever was available.

UPI/CORBIS-BETTMANN

On July 25, 1946, the United States detonated an atomic bomb just off the Bikini Atoll in the Pacific. This first underwater explosion of an A-bomb was evidence of the nation's decision to continue the nuclear weapons development begun before the war.

by T.A. Heppenheimer

REFLECTIONS ON THE COLD WAR

After the building of the atomic bomb in 1945, the Air Force asked airplane builders to invent the best way to deploy this new kind of weapon.

DELIVERANCE

SAN DIEGO AEROSPACE MUSEUM ARCHIVE

In 1947 Air Force contractors were testing missiles like the MX-774 (above) at remote Western sites. One of the first cold war confrontations to spur missile development, the Soviet blockade of Berlin, occurred in 1948, three years after Harry Truman (below, third from left), along with future president Dwight Eisenhower (far left), raised the U.S. flag in that city in 1945.

Fortunately, the Reaction Motors firm had what he needed. This engine, which generated 8,000 pounds of thrust, would steer the rocket by swiveling from side to side, a feature that demanded careful checkout on a test stand. "We called it the ditch digger," remembers Peter Palen, then a test engineer. "As the engine swiveled, it dug a tremendous ditch in the ground and blew the stuff all over."

The swiveling engines were a departure from the V-2, which was steered by movable vanes in the exhaust stream. Another difference lay in how each vehicle was designed to strike its target: For the V-2, the entire rocket was built to withstand the heat of reentering the atmosphere. But for the MX-774, Bossart designed a heat-protected pop-off nose cone containing the warhead—the only part of the missile that would hit the target.

By now the Army Air Forces was gaining independence as the U.S. Air Force, a service in its own right. But it could not escape President Harry Truman's postwar plan to decrease government spending. Facing budget cuts, the Air Force canceled Convair's contract on July 1, 1947, just as Bossart's men were completing the first test missile. But all was not lost: The Air Force granted permission for Convair to use the remainder of the MX-774 funding to build two more missiles and begin a test program for all three.

UPI/CORBIS-BETTMANN

By the fall of 1947, Bossart's team was ready to begin a series of static missile firings on the secluded coast of Point Loma, near Convair's aircraft division in San Diego. For each test, the 31-foot rocket, which looked like a tiny V-2, was suspended from an oil derrick that had been brought in to serve as a test tower. The first engine exploded, but after five more months of testing, Bossart grew increasingly confident in his swiveling-engine design.

On June 2, 1948, the test

COURTESY JEANNE BOLLAY

missile was trucked to an Army base in White Sands, New Mexico, to begin flight tests. In his 1960 book, *Atlas: The Story of a Missile*, John L. Chapman gives a detailed account of the MX-774 flight tests. Many of those who worked for Convair and the Air Force doubted if the MX-774 would even make it off the ground. But Bossart and his team ignored the skepticism. "They had confidence in their design and had come to White Sands for but one purpose: to make their 'bird' fly," writes Chapman.

On July 13, they were ready to launch their rocket from a modified V-2 stand, situated 600 feet from the blockhouse. If all went well, the MX-774 would rise 100 miles, and near the peak of its trajectory, an explosive charge would blow off the nose cone. Then a 40-foot parachute would deploy, returning the rest of the missile—as well as a camera and recording instruments—safely to the ground.

According to Chapman, cloud cover caused several delays, but by 6 p.m. the skies had cleared enough to proceed with the launch. Two dozen of Bossart's men gathered inside the blockhouse; a number of observers stood outside for a better view. Bossart and a range safety officer would watch from a trailer three miles away. At 6:05, the launch conductor pressed the firing button and the MX-774's four engines jumped to life, the rocket ascending smoothly. "She's rising fine," said the announcer's voice over the loudspeaker. "Very steady. She looks good."

By now some of the people inside the blockhouse had drifted outside for a better look. Shortly after the missile passed the mile mark, the announcer suddenly shouted: "Burnout! She's falling! Heading straight for the blockhouse!"

"Get those people back in here!" yelled an Air Force launch safety officer. Everyone made it back into the blockhouse. Seconds later a large explosion rattled the building and its occupants, but no one was hurt. As for the MX-774, its impact dug a crater 10 feet deep and 30 feet wide, leaving the missile in bits.

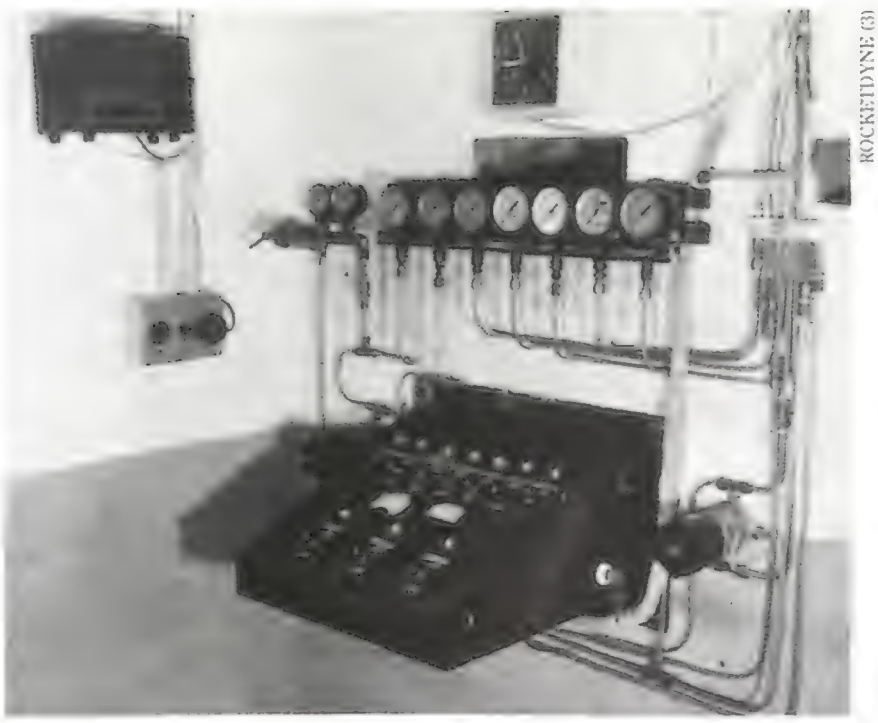
Bossart and his engineers returned to San Diego, where they pored over the data they had recorded from the brief flight, but they were unable to determine why the MX-774's engines had cut off so prematurely. They returned to White Sands two months later for the flight testing of missile number two. The second MX-774 did better, ascending 30 miles, but its engines too shut down early.

On December 2, Bossart's team made a third trip to White Sands for the final test flight. Sadly, the proceedings had a familiar feel, with the MX-774's engines once again shutting down too soon. "The third flight was the exact duplicate of the second," Bossart later declared.

Since his engineers had found the source of the problem (vibration from the engines had caused a valve controlling the flow of liquid oxygen to close), Bossart hoped for another chance to launch. But it wasn't in the budget. "The Air Force was very lukewarm," he said. "The project officer was a lower-echelon guy; they were even reluctant to send him to White Sands to see the flights." Ballistic missiles seemed "so far out in the future, out in the blue," he recalled.

A Navy lieutenant during the war, William Bollay (above, center) was sent to England to learn what he could from jet engine pioneer Frank Whittle (second from left). Later on, Bollay went to work for North American, where he oversaw the testing of rocket engines in a company parking lot.

ROCKETDYNE



ROCKETDYNE (3)

At the same time that Convair had received its missile study contract, the Air Force had handed out a similar one to North American Aviation, and the man who oversaw the study was William Bollay. Though only in his mid-30s at war's end, Bollay had already shown a knack for being present at the creation of important technologies. He had taken his Ph.D. at the California Institute of Technology, where one of his professors was Theodore von Kármán, a world leader in aerodynamics and a key advisor to General Arnold. Bollay's wife Jeanne recalls that "von Kármán would start thinking about 10 p.m., and they'd work till three in the morning. Then Bill would come in bleary-eyed, and he'd have an 8 a.m. class the next day."

In 1946, Bollay's Los Angeles-based team had to make do with improvised instruments (above) and a wooden shack for a blockhouse, but within three years they had relocated to better accommodations in the hills of Santa Susana.

Bollay worked with a group of graduate students who went on to found the Jet Propulsion Laboratory. He then joined the Navy shortly before Pearl Harbor, spending the war at its Power Plant Development Branch, a small center where a handful of people directed projects involving the development of rockets, ramjets, and turbojets.

The ramjet, or "flying stovepipe," offered particular promise, for it seemed the simplest engine imaginable: a carefully shaped tube fitted with fuel injectors. At high speed, air would ram in the front, causing combustion of the injected fuel. The hot airflow would blast out the back, generating thrust.

At the Navy's Applied Physics Laboratory in Baltimore, one group used nothing more complex than the exhaust pipe from a fighter airplane for the tube. A cluster of small solid-fuel rockets provided the initial boost, accelerating the ramjet to a speed where the air-ramming effect could come into play. In June 1945, APL scientists launched this arrangement from a makeshift ramp; it flew out over the Atlantic Ocean, reaching 1,400 mph, nearly twice the speed of sound.

Bollay's propulsion work for the Navy, particularly in the field of turbojets, brought him to the attention of James "Dutch" Kindelberger, the president of North American Aviation. Kindelberger brought Bollay in as a chief scientist and told him to establish a research group that could lead the company in new directions. Bollay set up shop in a red-brick building close to the Los Angeles airport. It had been called the tooling building but would now be known as the Aerophysics Laboratory.

Like Convair's Bossart, Bollay used the V-2 as a point of departure. Late in the war, German rocket engineer Wernher von Braun had built a winged version, the A-4b, seeking to stretch the missile's range with a supersonic glide. In a test flight, a wing broke off and the rocket came apart at altitude. Nevertheless, at the Air Force's development center at Wright Field in Dayton, Ohio, a small group of advocates were willing to bet that the A-4b might offer a route toward a missile with a range of up to 500 miles. In the same month that Bossart started work on the MX-774, Bollay won a $2.3 million, one-year contract to study the concept.

His rocket research began somewhat primitively in a company parking lot in Los Angeles, with cars sitting only a few yards away. A box-like steel frame held a rocket motor; a wooden shack housed instruments. The steel blade of a bulldozer's scraper shielded test engineers in case an engine blew up. Some of the engines were so small that they seemed to whistle rather than roar. "We had rockets whistling night and day for a couple of years," recalls J. Leland Atwood, who succeeded Kindelberger as president of North American in 1948. "We were feeling our way. We had no coordinated plan, but what we were picking up was all aimed toward propulsion, aerodynamics, or control. These were the pillars, or legs, on which things would be developed."

Eventually, Bollay would need to fire full-size V-2 engines, but he couldn't very well blast an employee parking lot with 56,000 pounds of thrust. He needed a new set of test facilities, preferably in a remote area where the engines' roar wouldn't bother people. "We scoured the country," recalls Atwood. "We located this land at Santa Susana Pass, on the hilltop." It was stark and sere, full of rounded reddish boulders, and it offered spectacular views of the adjacent San Fernando Valley. It was so rugged, though, that Bollay's associates had to use jeeps to get around.

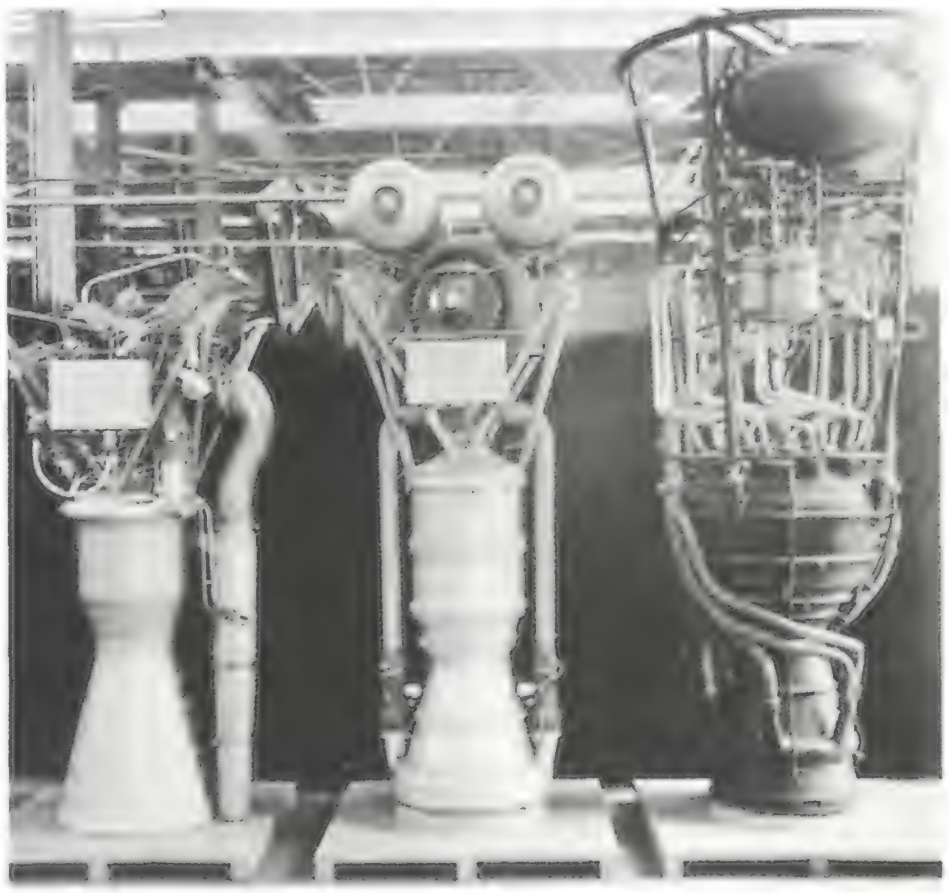
Early in 1947, North American leased the land and began to erect a rocket test center as part of a buildup that would cost the company $1 million. That was quite a lot amid the postwar stringency, but it showed that the company was strongly committed to a rocket-oriented future.

In February 1948, the Air Force told Bollay to stretch the range of his missile from 500 to 1,000 miles. He responded by proposing a winged rocket that would use ramjets to cruise at high speed. This design suited Lieutenant Colonel Edward Hall of Wright Field, who had been putting through funding for Bollay's rocket program; Hall's boss, in the next office, was funding the Air Force's ramjet R&D. (In 1948, the coterie of missile enthusiasts was that small and close-knit.)

Bollay would not try to build the ramjets; the Air Force left that part of the problem to the Wright Aeronautical Corporation, a major builder of aircraft engines. But the rocket motors used for takeoff would be all his own. His missile concept was named Navaho, reflecting a penchant at North American for names beginning with "NA."

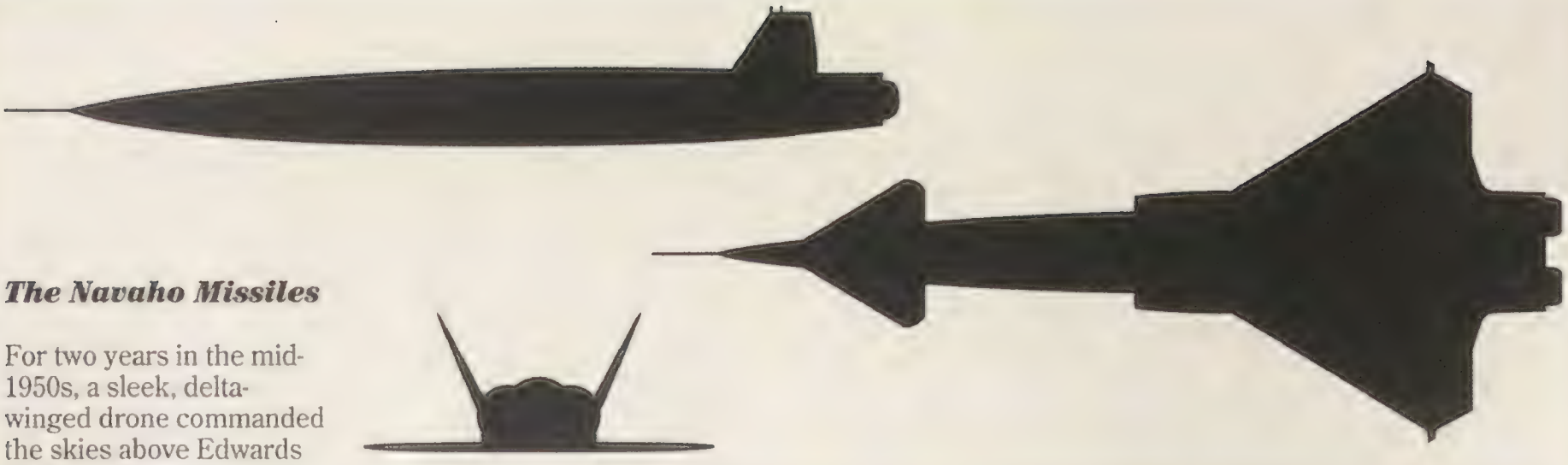
Why was the Air Force supporting a cruise missile when it had killed Bossart's MX-774 ballistic missile? Ramjets offered greater range. Further, according to Ed Hall, it was a matter of familiarity: "The Air Force is run by pilots; it's devoted to having guys fly airplanes. There was much more confidence in air-breathing engines than in rockets." And in the minds of Air Force generals, the ramjet-powered Navaho counted as a high-speed airplane, especially since it used a rocket only during takeoff—a technique similar to the Air Force practice of using small rockets to assist the takeoff of heavy bombers.

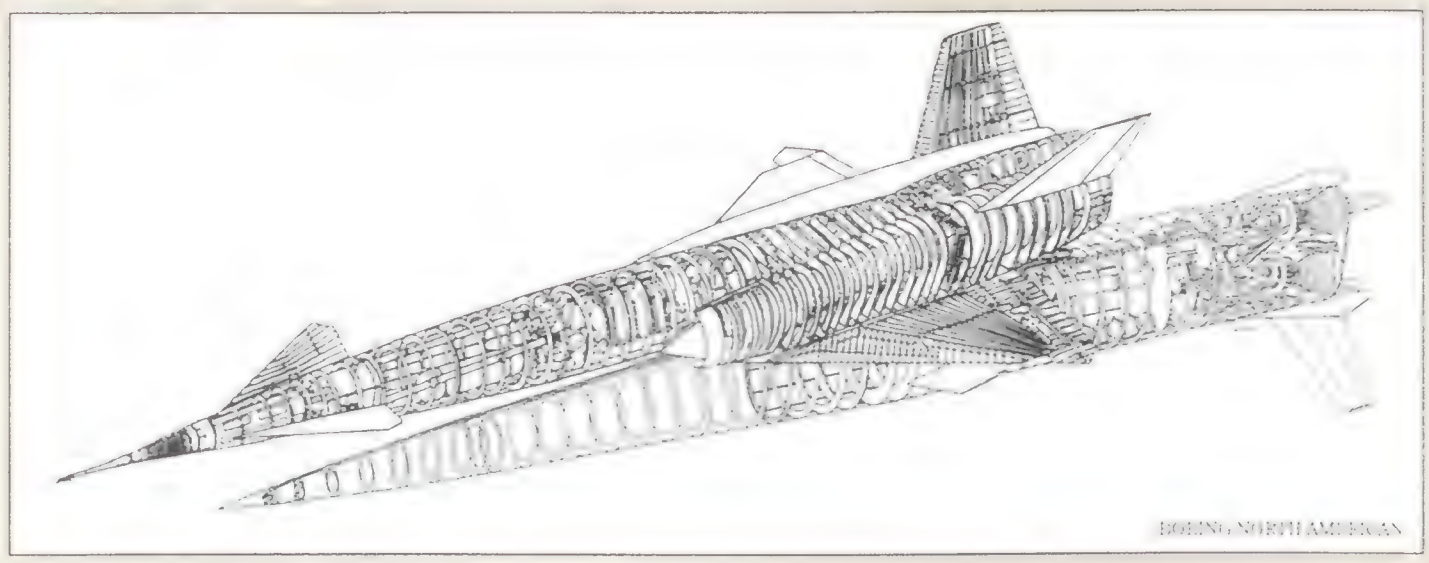
With Hall and other Air Force counterparts, Bollay settled on a thrust of 75,000 pounds for the rocket engines that would launch Navaho. That would improve on the V-2's 56,000 pounds. During 1949 it became clear that the effort to build such an engine needed a manager who could make decisions and push the project along. Bollay found his man in Sam Hoffman, a salty aircraft engine project leader who later became a professor at Penn State. His combination of industrial and academic experience closely matched Bollay's own. "I came out to get a rocket engine for them," Hoffman would declare. "Bill had a group of brilliant young fellows with no practical experience. Bill wanted me because I knew how to build engines, had built them, and brought practical experience to this young group."



Since Bollay had hired protégés of German rocket scientist Wernher von Braun to work for him at North American, his Navaho and Redstone engines (left and center) were kin to that of the German V-2 (right).

By November 1949 the first version of the engine was





The Navaho Missiles

For two years in the mid-1950s, a sleek, delta-winged drone commanded the skies above Edwards Air Force Base in California. Built by North American, the Navaho X-10 (above) was powered by two Westinghouse XJ40 turbojet engines. With afterburner, the X-10 had no trouble racing over the desert at Mach 2. The success of the X-10 flights paved the way for the construction of the even faster Navaho G-26 (right), which was launched by a liquid-fuel booster.

ready for testing at Santa Susana. It appeared lost amid the stark propellant tanks and looming steel girders of its massive test stand. With open platforms and stairways, the stand resembled an office building under construction. It stood amid wild country; one veteran recalls "the rugged rocky crags, the rattlesnakes, deer and raccoons, the smell of sage and exotic propellants." If all went well, a bright sword of yellow-white flame would stab downward from amid the girders, shaking the rocks with its roar.

The first tests were cautious, at 10 percent of full thrust and for only a few seconds. Then, as the engineers grew bolder, Sam Hoffman invited von Braun and several other bigwigs to watch the first full-thrust test. When everyone was assembled, the test conductor called "Main stage." The engine blew up.

It turned out that a designer had specified mild steel for a key part, not knowing that this common industrial metal would become brittle and shatter when chilled with liquid oxygen. Dutch Kindelberger, who was now company chairman, sought out the luckless engineer and reprimanded him: "You should have made the blasted thing out of solid gold!" After the affected part was replaced with one made of cold-resisting stainless steel, the engine achieved its rated thrust.

The development of the new engine was timely, for a deteriorating world situation now brought a sudden need for new weapons. The Soviets had already shown hostile intent during 1948 and 1949, overthrowing the democratic government of Czechoslovakia and attempting to seize West Berlin. Then in the early autumn of 1949, Mao Zedong took power in Beijing and proclaimed his country the People's Republic of China. At virtually the same time, Truman learned that Moscow had broken America's nuclear monopoly by detonating its own atomic bomb.

Facing threats from both Moscow and Beijing, Truman had to do more. A senior state department diplomat, Paul Nitze, advised him that "budgetary considerations will need to be subordinated to the stark fact that our very independence as a nation may be at stake." Suddenly the era of post-

Controlled by radio signals from a manned chase airplane, the unmanned Navaho X-10 (above) underwent a two-year period of flight tests at Edwards Air Force Base beginning in 1953. In the next phase of Navaho development, a liquid-fueled booster launched the ramjet-powered G-26 from Cape Canaveral (right).

SAN DIEGO AEROSPACE MUSEUM ARCHIVE

war demobilization was over, and money for a major military buildup would now flow forth quickly.

Accordingly, North American revised the design of Navaho. Bollay's staff had established that by leaping beyond approaches based on the old V-2, they could boost its range to 3,000 and even 5,500 miles. This meant building Navaho not as a winged rocket with auxiliary ramjets but as an unmanned supersonic airplane powered by two of the largest ramjets then conceivable: Each four feet in diameter, they would push it through the sky at 1,800 mph. The resulting craft had a stunningly rakish appearance, featuring delta wings and a double vertical tail.

Charlie Bossart (above) led the team that engineered the building of Convair's Atlas, which failed miserably in its first flight test at Cape Canaveral in 1957. But seven months later, in another test launched from the Cape, the nation's first ICBM was clearly ascendant.

This version of Navaho would need more power than a 75,000-pound engine could deliver, forcing Bollay to come up with an engine that produced 120,000 pounds of thrust. Two such engines, mounted at the base of a large booster rocket, would propel Navaho during launch. Rising into the sky, the missile would ride on the back of this booster, much as today's space shuttle rides its propellant tank. Then, high in the stratosphere and at supersonic speed, Navaho's ramjets would kick in, allowing the missile to separate from its booster and fly to its target.

As part of the new wave of military research and development generated by the fear of Soviet expansionism, other contractors were developing missile guidance systems. In December 1950, the RAND Corporation, an Air Force think tank, issued a report stating that long-range ballistic missiles now lay within reach. The Air Force responded a month later by giving Convair a new study contract, inviting Charlie Bossart to revisit his earlier concept for the ICBM called Manhattan.

For Bossart, it was like receiving a letter from a long-lost sweetheart. He called in three veterans of MX-774 and pulled his old reports from the files. In August 1951, he christened this missile Atlas, after Convair's parent company, the Atlas Corporation.

It would be a behemoth. It was to weigh 670,000 pounds, stand 160 feet tall, and be powered by seven of Bollay's new 120,000-pound engines. It was thoroughly unwieldy and represented only a basis for further studies, rather than a practical design for an operational weapon. Still, it stood as a milestone. For the first time, the Air Force had a concept for an ICBM using engines that were already in development.

Atlas was not yet an approved project, but that didn't stop Wright Field's Ed Hall from wanting to get started on the engines. "We had a hell of a time funding Atlas," he recalls, "so we did it through the back door, through Navaho. We used some of those Navaho funds to pay for developmental work on the rocket engines that later went into Atlas."

Hall understood that the engines required by Atlas needed to perform better than those of Navaho, which ran on alcohol. The 200-mile V-2 had flown just fine on alcohol, but

to carry a heavy nuclear warhead all the way to Moscow, Atlas would need a more energetic fuel, such as kerosene. Hall figured that the quickest way to bring about this change was to go straight to the man in charge at North American, Sam Hoffman.

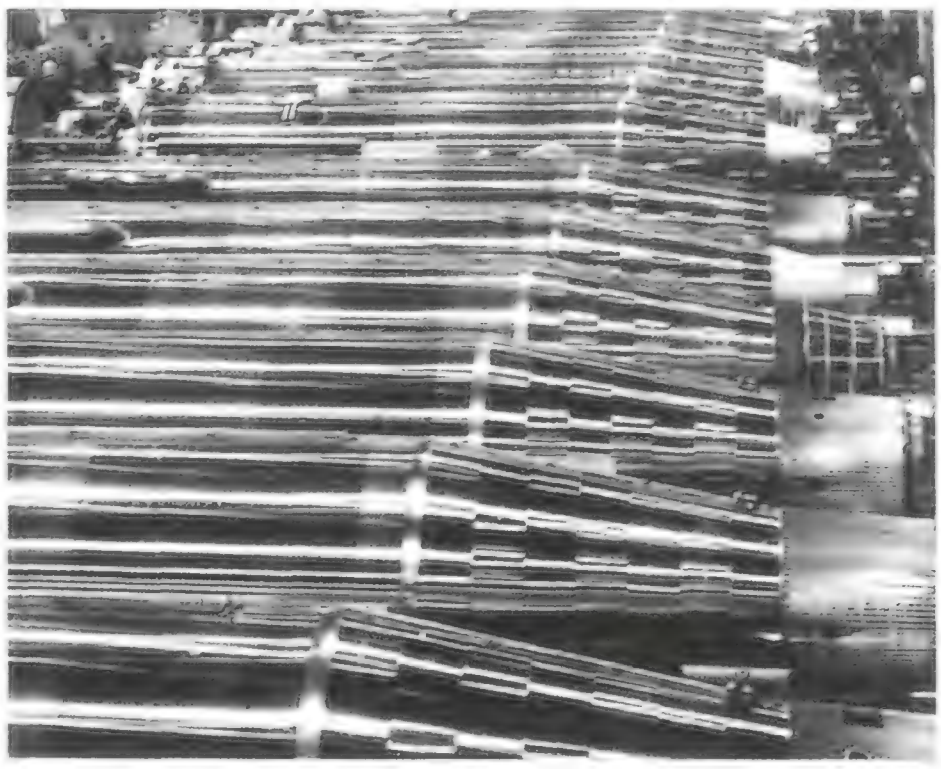
"I called him up," says Hall. "There were several of us on the phone. We said, 'Sam, we want you to lay out an engine for hydrocarbon use; we want you to throw the alcohol.' Sam was shocked. And his reasons were good—a hydrocarbon is a mixed bag of cats. You don't really know what's gonna happen. Sam was unhappy, and he let us know he was unhappy. We said, 'No, you have to do it, and we want 120,000 pounds.'

"There were several weeks when it was in the balance, and we told Sam that we much appreciated what North American had done on the 75,000-pound engine, but if his company would not take on the 120,000-pound hydrocarbon engine—we'd have to give [the contract] elsewhere. And Sam then collapsed and said okay." In January 1953 he initiated an effort called REAP, for Rocket Engine Advancement Program, to solve the problems that would arise in switching the Navaho engine from alcohol to kerosene. The Atlas engine that came from REAP gave Hall more thrust than he had called for: 135,000 pounds. But for the moment, Atlas was still something the Air Force was leery of buying.

NASM (2)

Convair's San Diego plant (above and below) churned out hundreds of Atlas missiles, which had a short-lived reign as ICBMs but a much longer one as satellite launchers.

The behemoth Atlas design that Bossart had put on paper in 1951 featured a correspondingly large warhead of 8,000 pounds. In 1952, the Air Force cut the warhead's estimated weight to 3,000 pounds, bringing a welcome reduction in the projected size and cost of the missile needed to launch it. But Navaho, which was to carry a similar weapon to Moscow, was still smaller and more compact, and Hall remembers why: "Its [ramjet] engines gave much better performance because they used atmospheric air" as an oxidizer for the fuel. As a rocket, Atlas would have to carry liquid oxygen in a tank, making it too big and bulky to win the support of Air Force generals, who didn't want to pay for the missile's excessive costs and undertake the difficult task of transporting it to launch sites. The Air Force also saw Atlas as an unattractive liability since the failure of just one of its seven rocket engines could cause the entire missile to blow up.



Another sticking point lay in Atlas' lack of accuracy. Experienced Air Force bombardiers could place bombs within 1,500 feet of a target, and the Pentagon requested that Atlas do as well when flying its full 5,500-mile range. But such accuracy corresponded to hitting a golf ball a mile and having it fall right in the cup. Unfortunately for Convair, there was no way that Atlas could meet that requirement. It would miss by miles, and no one knew how to build a better guidance system.

A potential solution to these obstacles came on November 1, 1952, when the U.S. Atomic Energy Commission detonated the world's first hydrogen bomb on Eniwetok Atoll in the Pacific. "The thing was enormous," one observer said. "It looked as though it blotted out the whole horizon, and I was standing 30 miles away." Theodore Taylor, a weapons designer, described it as "so huge, so brutal—as if things had gone too far." Yielding a 10-megaton explosion, the bomb vaporized an island, and suddenly the accuracy of a weapons delivery system started to seem less important.

The history-making event drew the attention of Bernard Schriever, a youthful colonel in the Pentagon who had the responsibility of keeping track of new technical developments and alerting his superiors when anything interesting came along. The Eniwetok explosion did not count as such a development, for its bomb was far too heavy to serve as an operational weapon. But in April 1953, Schriever received a briefing from Edward Teller and John von Neumann, two of the nation's leading weapons

NASM (2)

Using a secluded test tower at Sycamore Canyon, Convair could run up each missile's high-decibel engines without disturbing civilians.

designers. Schriever recalls: "Both of them stated that a weapon was feasible. It would weigh no more than 1,500 pounds and have a yield of a megaton."

Schriever, who had a strong interest in Atlas, knew he had just heard solutions to the problems of the missile's large size and poor accuracy. A compact warhead would permit construction of a compact ICBM, small enough to win support. In addition, even if Atlas missed its target by several miles, the megaton warhead would still destroy it, plus everything that lay between. "Here was a breakthrough that made the ICBM very feasible," says Schriever. "It wouldn't require a rocket as big as the Empire State Building."

Within the initially doubtful Air Force, the tide began to turn. "Ballistic missiles [are] here to stay, and the Air Staff had better realize this fact and get on with it," said General Thomas White, one of the Air Force's most influential officers. Using missiles to deliver nuclear weapons also had the advantage of not subjecting bomber pilots to the blast of a hydrogen bomb. In May 1954, White assigned Atlas a 1-A priority, the Pentagon's highest. Schriever, who had become a brigadier general in the two years since Eniwetok, set up an organization to manage its development and made Ed Hall the propulsion officer.

Meanwhile, over at North American, though Kindelberger and Atwood took heed of their competitors, they still believed strongly in Navaho. Bollay's team had completed the design for the first test missile, the X-10, which would take off and land on runways like a conventional airplane. In his 1996 book *The Navaho Missile Project*, James N. Gibson writes of this 66-foot delta-winged creation: "The X-10 mock-up was more than impressive, it was futuristic." The missile would rely on two turbojet engines—instead of the planned ramjets—to give it the juice to fly at Mach 2 and climb at 20,000 feet per minute.

It was around this time that the Navaho project lost Bollay's leadership; he left North American in 1951 after a long-running disagreement with his boss, Larry Waite, over management style. But Bollay had poured a strong foundation, and North American would go on to build thirteen X-10 vehicles.

In May 1953, the first X-10 was shipped to Edwards Air Force Base in California to begin runway taxi tests. Flying as a drone, the X-10 would be controlled by radio from a manned chase airplane and by a ground control station. On October 14 it was ready for its first flight. According to Gibson, who studied the *Air Force Missile Test Center History*, a chronology published from 1952 to 1959, X-10 no. 1 easily cleared the east-west runway at Edwards and lifted into the air for a half-hour run before landing on Rogers Dry Lake. It performed well, accelerating to Mach .75 and achieving an altitude of 21,000 feet. For the Navaho engineers, the years of design work and the long hours of wind tunnel testing had paid off in a big way. They had an aerodynamically stable vehicle that could take off, accelerate rapidly, and land—all without the aid of an onboard pilot.

The flight testing at Edwards continued, with the X-10 progressively increasing its altitude and speed. The third flight of X-10 no. 2, however, which took place on July 1, 1954, gave engineers a scare. "Takeoff, gear retraction, and climb out were normal," writes Gibson. "Then at about 17,500 feet, the airborne controller saw a long flame coming from the vehicle." He gave a command to cut the afterburners, and when he realized that the engines were not the source of the fire, he issued the destruct command, which didn't work. The controllers then tried to steer the X-10 to the north, but the autopilot had failed. The missile pulled up into a steep climb and refused to follow any radio signals. Eventually the engines died, and the missile leveled off at 5,000 feet and started to descend. Near Cuddeback Lake, it hit the ground hard, bounced into the air, and burst into flames. X-10 no. 2 was gone, and nothing remained but a clean outline of the missile's planform carved in the sand.

Despite the loss, North American's engineers would chalk up the Edwards flight testing as a success. They had built a responsive autopilot and a missile that had no trouble flying straight and level at supersonic speeds.

The next step in the Navaho program was the design and construction of the G-26, a test missile that had essentially the same design as the X-10 except that it would be launched while mated to the back of the liquid-fuel booster and pow-

ered by two ramjets instead of the X-10's turbojets.

By late 1956, the Navaho crew was making preparations to begin flight testing the G-26 from the Cape Canaveral Air Station in Florida, where a whole community of potential additions to the U.S. arsenal had set up shop: Northrop's Snark, the Army's Redstone, and Convair's Atlas. On November 6, everything was ready. If all went according to plan, the test would determine how well the booster rocket would perform and how much the G-26 would be affected by vibration and flutter. According to Gibson, the booster's engines fired successfully and achieved full thrust, sending the booster and the piggybacked G-26 roaring into the air. But after only 10 seconds, the missile and booster started to pitch up and down, violently out of control. This caused a structural failure, and 16 seconds later, a catastrophic explosion, which sent pieces of the G-26 and booster raining into the Atlantic. (It turned out that technicians had installed the pitch rate gyro backward.)

Unfortunately, that first flight was a sign of things to come. For the next seven launch attempts, a series of glitches would keep the G-26 frequently grounded, earning it the name "Never Go Navaho." In March 1957 the North American team finally got G-26 into the air again, hoping this time to observe the missile's flight characteristics as well as the performance of the ramjets. But the booster didn't generate full thrust, and when the missile and booster separated, the G-26 was traveling at only Mach 1.3, a speed too low to ignite the ramjets. Without power, the G-26 had nowhere to go but down, landing in the ocean 25 miles away from the launch site.

Four months later, on July 13, the Air Force canceled the Navaho contract, deciding that a Mach 3 cruise missile was not the way to launch nuclear weapons at an enemy more than 5,000 miles away. Navaho's poor showing at Cape Canaveral hadn't helped its cause, but other contenders weren't faring much better. An engine failure that occurred during the first Atlas launch, on June 11, had resulted in a paltry altitude of only 10,000 feet, forcing the range safety officer to blow the missile up.

The Navaho people had done brilliant work, but with Atlas ascendant, the Air Force had kept Navaho in the picture only as a backup. When it became clear that Atlas would succeed, Navaho met a swift end. "It came just as all cancellations come—out of the blue," Atwood recalls. "It shocked old Dutch quite a lot. I didn't have much hope for saving it, but I thought he should protest anyway. Dutch went to Washington and tooled up and down the Pentagon halls. But it didn't do any good."

No one disputed the elegance of the Navaho design. Still, amid the rapid pace of missile development, Atlas was passing it by. The operational Navaho needed five engines—three rockets and two ramjets. It was more complex and thus more failure-prone than Atlas, which used three rocket engines period. In addition, Atlas would fly much faster. "Navaho would approach the target at Mach 3," says Lee Atwood. "A good anti-aircraft missile might shoot it down. But Atlas would come in at Mach 20. There was no way that anyone would shoot it down." Given the opportunity to buy a simpler, faster missile, the Air Force went with Atlas.

The Air Force deployed 126 Atlas ICBMs at air bases across the country, including Vandenberg Air Force Base in California (below). But it did not do away with its fleet of long-range B-52 bombers. In a 1960 publicity photo captioned "Power for Peace," the Air Force showed off its two-pronged deterrence strategy.

I thought I had walked in on the punchline of a bad anti-Navy joke. A former Army pilot told me (a little too gleefully) that a whole squadron of Grumman A-6 Intruders had been sunk off the northeast coast of Florida, and suggested the Navy name its new Intruder base "Naval Air Station Atlantis." But when I checked out the story with Northrop Grumman's plant in St. Augustine, production and operations manager Steve Blalock told me it was indeed true. The A-6s, until recently the Navy's premier attack craft, were being dumped to make some sort of marine habitat. Blalock went on to give me the details of the retirement of the A-6 and how several dozen had ended up as fisheries.

In the late 1980s, Intruders were being sent to Grumman's St. Augustine facility to be overhauled and refitted with new wings made of composite materials. Some of the all-metal wings were over 20 years old, and the Navy was concerned about metal fatigue. That fear was borne out in 1987 when a wing failed on an A-6 executing a high-G pull during a practice bombing run at the Navy's El Centro facility in California.

The Navy established a replacement-wing program, and Boeing Military Aircraft won a $588 million contract to produce one-piece graphite-epoxy composite wings for 120 aircraft. Grumman-St. Augustine retained control over the final reassembly of 72 as well as manufacturing 120 kits to mate the wing to the fuselage. Eventually, an overhaul would extend the service lives of 300-plus A-6s well into the 21st century.

Before the structural failure, the Intruder had earned a reputation as a rugged street fighter, able to deliver 15,000 pounds of bombs with pinpoint accuracy in the black of night and in miserable weather to targets 1,000 miles away. The airplane was developed af-

The Navy's A-6 Intruder is retiring, and what could be a more fitting end?

BURIAL AT SEA

Story and photographs by Erik Hildebrandt

A barge carries dismembered Grumman A-6s to a drop site off the coast of Florida, where they will start a new career.

ter the Korean war in response to the Navy's need for a low-level, long-range, all-weather attack jet, and the Intruder embodied all that was new: inertial navigation, terrain-avoidance radar, integrated computer controlled attack system, and side-by-side pilot and navigator/bombardier seating for better crew efficiency. From its 1965 combat debut in North Vietnam, screaming in on targets at treetop level along the Ho Chi Minh Trail, to its 1991 role in Desert Storm, the Intruder's ground attack proficiency had been continually enhanced. The current Intruder variant, the A-6E (the last of which is slated to retire in 1997), is the Navy's most accurate and long-reaching attack aircraft with both conventional and nuclear capabilities.

"The thing I love about this plane is that it takes an honest, hard-working pilot to fly it well," says Lieutenant Patrick Day, an A-6 pilot aboard the carrier *Enterprise*. "You can't hide behind a sophisticated autopilot; there's no computer fly-by-wire to make you better than you really are. Flying the Intruder is all hands-on. The low-level overland bomb runs are where this plane really shines from a pilot's perspective. It's what tactical flying is all about: pushing over, rolling out, releasing, and yanking 'til it hurts to get away."

But by the 1970s, the specialized single-purpose mission that built the Intruder reputation had become its Achilles' heel. New airplanes, like the McDonnell Douglas F/A-18, could take on more than one role. Additionally, modern ease-of-maintenance concepts were being built into aircraft entering the fleet, while the Intruder was stuck with a 1950s layout. It became increasingly difficult and grossly expensive to tear the aircraft to the bone each time a new system had to be installed. Basic systems—hydraulics, fuel management, primary wiring—designed generations earlier were becoming antiquated. Today it takes 44 hours of maintenance per hour of flight time to keep an A-6 going. (The airplane slated to replace the Intruder, the F/A-18 Hornet, requires only about a 17:1 ratio.)

When the decision was made to retire the A-6, the upgrade program ended quickly. On Friday, September 17, 1993, Grumman received a "stop work" order from the Navy. Employees at the facility refer to that date as Black Fri-

Regardless of their future, all aircraft had to undergo "demilitarization and decontamination" before leaving the Grumman facility (above). Afterward, some went to museums, some went to storage, and some 70 became fisheries. In the picture at right, spadefish and juvenile red snapper (far right) investigate a wing. (No pilot fish have yet been spotted.)

Serving the Navy for more than 30 years, the Intruder earned a reputation as a street fighter, and over its service life it was equipped to the gills with the latest attack technology. But nothing in its arsenal had prepared it to win a battle with the Pentagon. When the "stop work" order came down, the end was mercifully quick (left and below).

day. "Literally, we were working one day full tilt on the refit, which promised Intruder feasibility beyond the year 2000, and the next thing we know we were calling back jets that were in the middle of flight testing," says Steve Blalock. "A 'stop work' order from the Navy means you stop work *now*." In the course of one day, Grumman moved from upgrading 80 A-6s to preparing to tear them down. After the stop-work order, the company laid off more than 300 employees.

Once word got out that the Intruder program had been canceled, several museums requested A-6s for their collections. Six went to museums and a few were sent to Naval bases to be mounted on poles as "gate guards." Eventually most of the organizations that requested aircraft got them. Still, that hardly made a dent in the number of airplanes that were sitting at Grumman-St. Augustine marked for destruction.

Regardless of its disposition, each aircraft had to undergo demilitarization and decontamination. "To get these planes ferriable, all hydraulic fluids, fuel bags, and about 50 other items have to be neutralized, removed, re-utilized, and inspected before they could leave our facility," Blalock says. "Once they were clean and all the requests for airplanes had been filled, we began to sell the rest off for scrap, and quite honestly, it was depressing."

In the midst of the gloom and doom at Grumman, Blalock hatched a plan to assign a new mission to the Intruder and provide his hometown with an environmental and economic boost.

The waters off Florida's northeastern shore consist primarily of barrier beaches with some rock reefs close to shore. A largely featureless ocean bottom stretches beyond these inner reefs for 50 miles to the Gulf Stream and Continental shelf. This offshore oasis has supported the majority of the region's fish stock, both sport and commercial.

In the early 1980s south Florida's first artificial reefs were deposited some five miles offshore in an attempt to attract marine ecosystems. By monitoring the new reefs as well as local commercial and sport fisheries, marine scientists proved that placing man-made objects on flat, sandy areas of the ocean floor attracts and supports a significant amount of marine life.

The majority of Florida's nearly 400 artificial reefs consist of concrete rubble from the ongoing demolition and replacement of the state's aging waterway bridges. But increased commercial demand for this recycled material has sent prices skyrocketing. Communities interested in artificial reefs are searching for cheaper alternatives. Blalock, a member of the St. Johns County Reef Research volunteer dive team, which provides mapping and monitoring data for the county's artificial reefs, says, "It wasn't too big a leap to make the connection that Grumman's sanitized airplane fuselages could be used in our own reef program."

The huge military training presence in St. Augustine during World War II regularly deposited airplanes into the surrounding ocean, and the crashes had littered local waters with an abundance of aluminum mini-reefs. Blalock's reef research dive team helped the county apply for a grant from the Florida State Department of Environmental Protection, which was interested in a study proposed by the dive group: an investigation into local fishermen's lore that some fish prefer aluminum reefs.

Third-generation charter boat captain Frank Timmons Jr. routinely makes runs to the airplane reefs for his customers. "The oldtimers can tell you stories of pulling 30,000 pounds of prime

Production manager at Grumman's St. Augustine facility and also a diver, Steve Blalock proposed that Intruders be sunk to create artificial reefs.

To create a second reef, a barge carried three loads of Intruder carcasses to a site 30 miles off Daytona Beach (left and above). According to the author, "The sound of the crane tearing at the planes was enough to make you ill if the rocking boat hadn't already" (right).

"As a Grumman guy, it broke my heart," says Blalock. "But as a diver I was excited. We were creating something really important out of this otherwise sad loss. Besides, they were all headed for the furnace anyway, so at least we were saving them from that." As for the A-6s still in the fleet, most will join others in storage at Davis-Monthan Air Force Base in Arizona.

The following week the team dove on the site. "The bait fish are the first to arrive, usually within the first hour of sinking a reef," says senior team member Jim Netherton, a chemist at the University of Florida's Whitney Laboratory. "Next come the toothy pelagics like amberjack, king mackerel, and barracuda after the first week. Within a year, the tiny reef pickers that eat the algae as well as the bottom fish are living there full time. On that first dive, we saw clouds of bait fish with the occasional jack, but our primary objective was to measure and map the site. We'll do fish counts every six months and compare them with a concrete reef we put in about three miles north of here."

I asked Frank Timmons about the St. Augustine Intruder reef. "Oh yeah, it attracts the fish all right," he said. "And the charter boats and the sport fishermen and the commercial divers and the sport divers. There is so much fishing pressure on that reef now that on weekends I can't hardly get near it.

red snapper off spots we called 'bonanzas' in the '50s," Timmons says. "We fished the hell out of 'em."

Timmons recalls a place called Paul's Wreck off Flagler Beach, south of St. Augustine: "In the old days you named a spot after the guy who found it, and usually a spot was kept secret for as long as possible. But we heard whispers about this particular place, and my dad managed to get pretty close to where Paul's Wreck was supposed to be. We snuck up and busted 'em cold and ended up fishing that spot almost every day for the whole summer. Off that wreck alone I caught enough snapper to pay cash for a brand-new Camaro."

When Timmons got older he dove on the old sites to learn what attracts fish. "When I dove Paul's Wreck, it turned out to be some sort of military jet plane half-buried upside down in the sand," he says. "The wheels stuck straight up and there was even air in tires that I'd let out each time I dove it. It turned out that almost all the 'bonanzas' I dove on were some sort of airplane or other. Oldtimers swear it's the aluminum that attracts the snappers, but I think it's just because the planes are so small and hard to find that they hardly ever got fished."

In short order, both Florida's Department of Environmental Protection and the Navy gave the Intruder reef project the green light, and on June 16, 1995, nearly two years after Blalock had first floated the concept, a bulldozer and a backhoe manhandled a bargeload of 26 Intruders into the water 25 miles off St. Augustine. Five days later, another 18 followed.

It's so easy these days to find things with LORAN and GPS that anyone with a boat and motor can go out there."

Last July I traveled to Grumman to take photos of the final drops for the Intruder Ball, an east coast squadron party to be held early next year, when the last A-6 squadrons will be decommissioned. Having been rinsed of toxins and stripped of their former glory, another 26 airplanes were laid out in two lines to wait for the barge.

This batch had been acquired by the Volusia County Port Authority at Ponce Inlet near Daytona Beach, where Frank Timmons had heard about the St. Augustine reef. Eager to replicate the results in his home fishery, Timmons fed the tip to the board in charge of Volusia County's reef program.

"We wanted to create a linear reef that stretched for a half-mile instead of just one big pile to see if that would attract more fish," says Ponce Inlet Port Authority director Dan O'Brien. Another difference would be its depth. "There's a considerable insurance liability associated with these sites," he adds. "We hope to deter the sport and spear-gun divers with not only the 30-mile boat ride but also with the more extreme depth of the water, which is around 130 feet."

The next morning I returned to the ramp to help the Grumman mechanics load the barge. As a tribute to the A-6, the mechanics had re-fitted a golf cart with parts from the stricken airframes, including ejection seats and a retractable tailhook. "After the rollout we had people coming over from all across the field just to get a look at [the cart]," says Rich Gavin, an ex-Navy maintenance man who had worked on Intruders. "It was a hit with everyone and it broke the tension around the place when everyone needed something to laugh about." The self-proclaimed "junkyard dogs" had created a company mascot.

By late morning, the barge, bearing the first of three loads, was headed down the intercoastal waterway, and the next afternoon it was in place 30 miles off Daytona Beach. Buoys marked the four corners of the permit site. The plan was to tow the barge diagonally across the square while pushing the airplanes over the side.

The sound of the crane tearing at the airplanes was enough to make you ill if the rocking boat hadn't already. The crane would grab a jet by the scruff of the neck and try to force it into the water. The Intruders seemed to resist, repeatedly breaking loose and crashing down on the airplanes beneath them.

By the time the last few jets were left on the barge, I had gotten all the pictures I wanted from the surface and was poised to shoot the last airplane as it sank. It remained upright, floating on the surface longer than the others. I swam near and it slowly banked toward me, air rushing out everywhere in breaths of mist. With one last gasp, the Intruder slipped below the surface. The airplane swam directly under me in a gentle right turn, streaming bubbles. In 30 seconds it had disappeared.

A clipped-wing Intruder makes its final approach to Naval Air Station Atlantis.

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THE LATEST WORD ON TOURS AND LEARNING ADVENTURES

During World War II, liquid-cooled piston engines did more than their share to help secure victory. The U.S. Allison V-1710 in the P-40 Warhawk and P-38 Lightning and the British Merlin in the Hurricane, Spitfire, and P-51 Mustang were "fighter" engines: two banks of six cylinders arranged in a "V" not much wider than the pilot's shoulders, the whole thing shoehorned into a slim cowling that parted the air like a stiletto. The Allison notwithstanding, the Americans had a preference for air-cooled radial engines, and liquid-cooled engines were a primarily European technology. It was the license-built Merlin that made the Mustang a legend (see "Who Made the Mustang?" Aug./Sept. 1996), and after the Allisons, no American liquid-cooled V was produced in volume.

In the United States today the only aircraft piston engines of any kind in volume production—leaving aside for a moment the issues of liquid cooling and the V configuration—are produced by Teledyne Continental Motors (TCM) and Textron Lycoming. The two companies offer primarily air-cooled engines that have cylinders opposed in a horizontal, or "flat" layout, and produce 100 to 425 horsepower. They have been used primarily in light, general aviation single- and multi-engine airplanes. (TCM wraps the cylinders in water jackets to cool its "Voyager" series engines, but the layout is unchanged.)

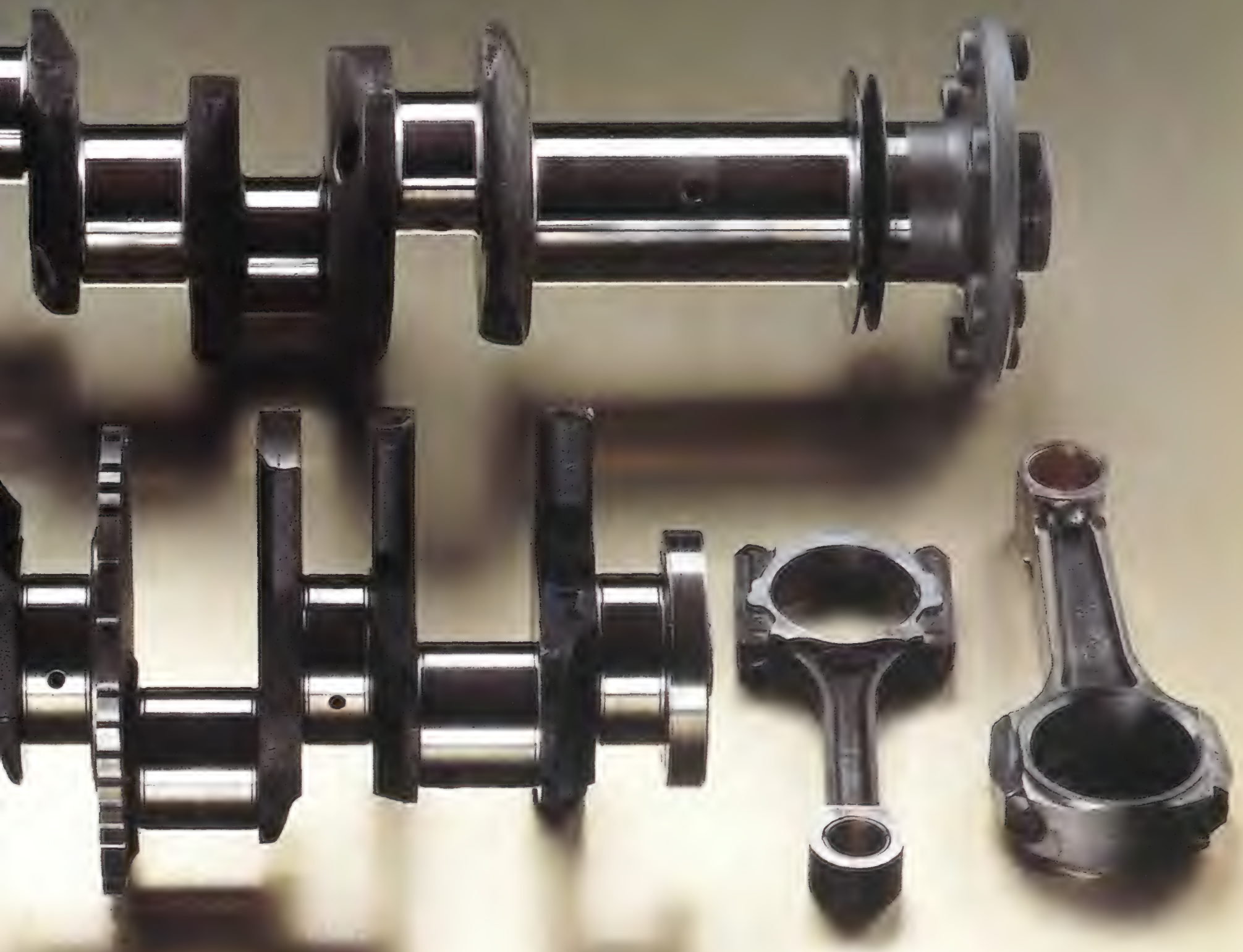
With the exception of these small engines, the piston engine has been replaced in aircraft by the powerful, lightweight turbine. Even in Europe the liquid-cooled V has long been extinct, and today, not a single modern descendant of the thundering Merlin has made its way into a current aircraft. The largest U.S. piston engine for aircraft made today is the 46-inch-long eight-cylinder Lycoming IO-720 rated at 400 horsepower. An Allison 250-B17, the closest comparable turbine engine, produces 420 shaft horsepower but weighs only 35 percent as much as the big Lycoming. It makes up for the lower weight with a higher price,

ROBERT T. VanMARTER (2)

Power Struggle

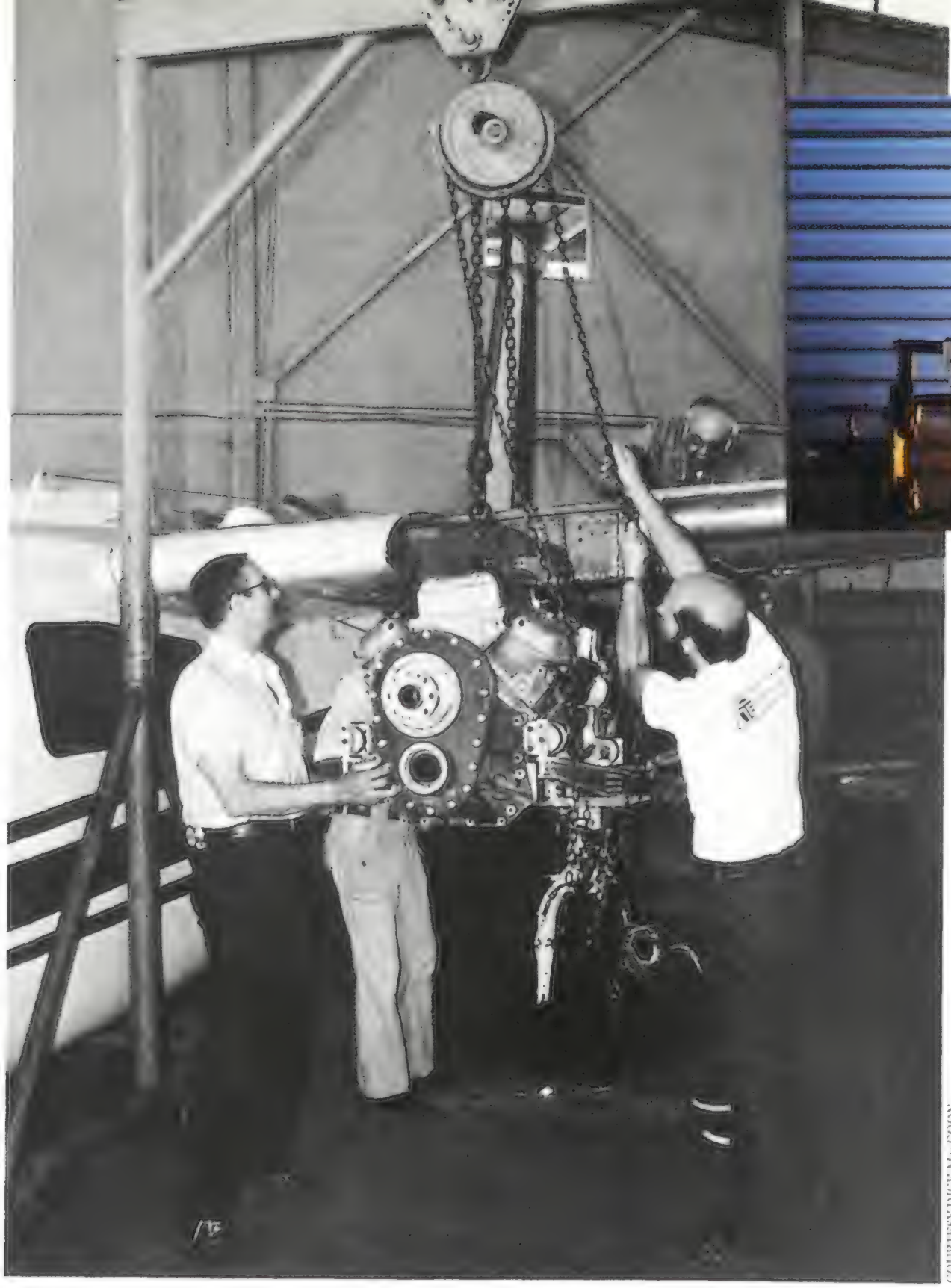
Why car engines won't fly.

by Don Sherman



The crankshafts and connecting rods of two 300-horsepower engines illustrate the stark differences between automobiles and aircraft. The Cadillac Northstar V-8 crankshaft (foreground) has five main bearing journals, all narrower and of larger diameter than the four connecting rod journals, each of which is linked to a pair of pistons. The large toothed ring near the middle of the crankshaft governs spark timing. The Lycoming IO-540 crankshaft (background) has four main bearing journals, including the extra large one for the propeller at the front end (right) and six connecting rod journals, one for each cylinder. The cooling fins on each cylinder increase the engine's intercylinder distances, making the crankshaft considerably longer than the Cadillac's (inset). Because of their length, combined with a more severe operating environment, aircraft cranks must be made heavier than a car's.

CHAD SLATTERY



COURTESY DICK MacCOON

Dick MacCoon (above) tapped the motor racing community to develop the Thunder engine from a racing version of a Chevrolet V-8. In tests on an Aero Commander twin (left), the engine developed horsepower without adverse vibration or overheating.

however. So between roughly 400 and 500 horsepower, where you might expect some overlap and active competition between pistons and turbines, there is instead a gap, and in terms of price alone, the gap is more like a canyon.

The inherently compact arrangement of two banks of cylinders in a V-shaped block lives on in the automobile, where it thrives today in V-6s, V-8s, and a few V-12s. Now two enterprises, working completely independently, want to take the liquid-cooled V back from the automotive industry so they can return it to the airplane and fill the piston-turbine gap. The problem is that the liquid-cooled V is an automobile engine now. There is no airplane left in it.

The idea of powering light airplanes with automobile engines is hardly new (see "Classical Gas," p. 76). For years experimenters and homebuilders have been drawn to converted automobile engines because they're relatively cheap and plentiful compared to aircraft engines, which are manufactured in much lower volume. Many also complain that while the "Lyconental" technology has grown stale, automobile engines have enjoyed rapid advances, with such innovations as overhead camshafts, multi-valve combustion chambers, and microprocessor-controlled fuel-injection and ignition systems, to name a few.

For aircraft, there are inherent advantages in both liquid cooling and the V layout. Liquid cooling allows cylinders to be packed closer together, which results in a shorter, stiffer crankshaft, and the V configuration is narrow. Although the only source for such engines is the automotive industry, neither team working on the two current projects will simply pull a Buick block out of a boneyard and stick it in a biplane. First they have to strip the car out of the engine and put some of the airplane back in.

One enterprise pairs United Technologies' Hamilton Standard division with the Toyota Motor Corporation. Hamilton Standard's effort employs advanced technology and enjoys the deep pockets of one of the world's wealthiest industrial groups. But the partners are so secretive that not much is known about their plans.

The second player is the Orenda Division of Fleet Aerospace in Ontario, Canada. There are no secrets about the Orenda team's plan. They have taken aim at nothing less than the world's most popular turbine: the Pratt & Whitney Canada PT6 family of turboprops.

To understand why something so seemingly easy as adapting an automobile engine to power an airplane isn't really easy at all, it's essential to acknowledge that all piston engines are not created equal, and that moving a car down the road has little in common with propelling an airplane through the air. The key difference between automobile and aircraft engines is the intensity and duration of loads placed on them, or their "duty cycles."

One of the most sophisticated automobile engines currently in production is Cadillac's Northstar V-8. Light and compact, this 279-cubic-inch prime mover generates 300 horsepower from a 400-

Why an Airplane Is Not Like a Car

Both cars and airplanes exact their share of torture on an engine, it's just that the nature of the torture is different. Because the output shaft of any engine is an extension of the crankshaft that turns the pistons' reciprocating motion into rotary motion, the crank is the place where stress and strain have the most direct effect.

When your teenager pops the clutch to make the tires chirp, there's a massive flywheel and built-in driveline flexibilities (tire slippage, for one) to protect the crankshaft from excessive stress. Automatic transmissions provide fluid-filled torque converters that keep the shock from the occasional pothole from being passed on to the crank (Figure 1).

Under normal circumstances aircraft engines have no shock loads to contend with. Instead, their cross to bear is torsional vibration. The simplest illustration of torsional vibration is a rubber-band-powered flying model. Like the rubber band, an airplane's propeller shaft has an inherent flexibility that extends all the way through the crankshaft and any drive system or reduction gearbox to the point where the propeller is attached. Every time a cylinder fires, portions of the driveline are twisted or wound up with respect to the rest of the system. And like the rubber band, these wound-up portions spring back. This repeated twist and untwist is torsional vibration in its simplest form.

On a car, flexible driveline elements such as the tires and the torque converter absorb torsional vibration. But the airplane's propeller is a large mass that can contribute torsional vibration of its own to the crankshaft. In fact, the flexibility of the propeller drive and the propeller's rotating inertia constitute a torsional system (Figure 2).

Every torsional system has a natural or resonant frequency analogous to the pitch of a plucked violin string. Rubber-band models have a very low natural frequency of only a few cycles (wind, rewind) per minute. Airplane engines and propellers have much higher resonant frequencies and usually several of them. The plot of torsional vibration versus speed for a Merlin V-12 is a roller coaster of a dozen or more peaks and valleys. In addition to firing impulses, other disturbances such as a change in prop pitch can influence torsional vibration characteristics. Problems arise when some vibrational disturbance coincides with the system's natural frequency. After the accumulation of so many twist cycles at its natural frequency, the crankshaft is susceptible to local cracking followed by total failure. Severe torsional vibrations must be analyzed by engineering tests and either eliminated or labeled "critical speed" in operational manuals so they can be avoided during sustained cruising.

Another means of avoiding torsional-vibration problems is to use a very short, very stiff crankshaft, one of the prime advantages of a radial engine. But in opposed cylinder arrangements or in V engines, air cooling mandates greater inter-cylinder distances to provide room for cooling fins. A liquid-cooled V has an inherently compact layout that leads, in turn, to shorter, stiffer crankshafts.

ILLUSTRATIONS BY FRANK KULCZAK

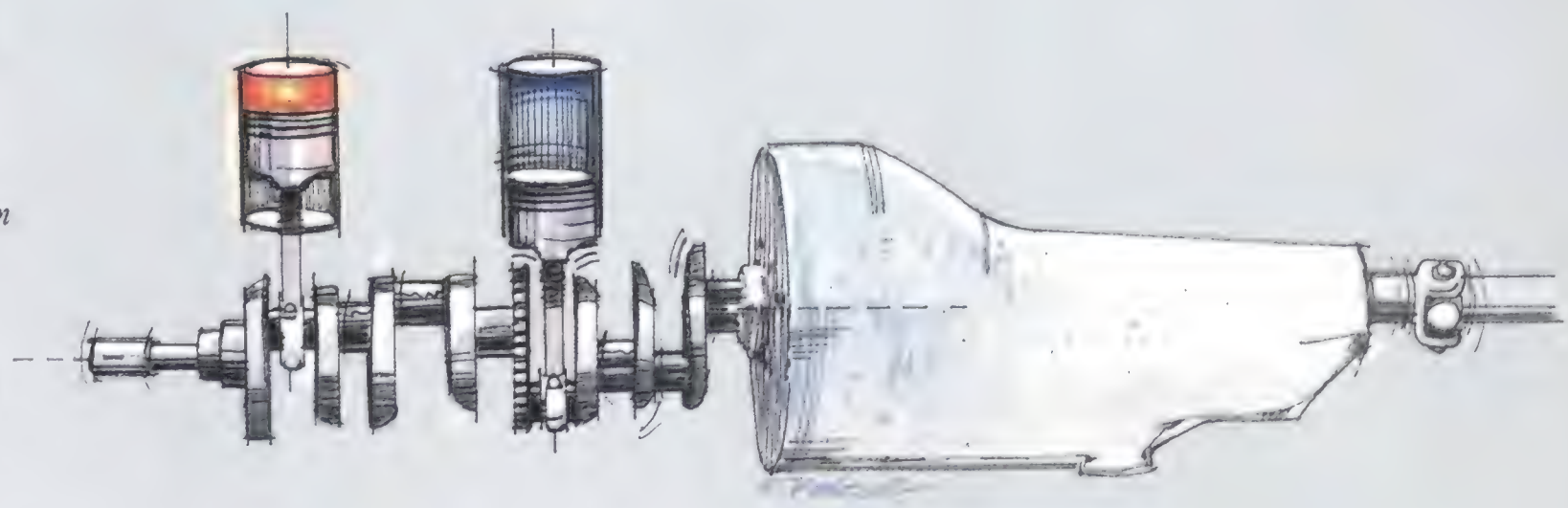


Figure 1 *Automotive engines are subjected to sudden acceleration, long periods at idle, and shocks from irregularity in the road surface that can be transmitted to the engine. When an individual cylinder fires, the force from the combustion of the fuel-air mixture causes a momentary twisting, or torque-wise, force to be imparted to the crankshaft. But just as the car's driveline tends to absorb road shocks, it also dampens the forces that create torque-wise vibration.*

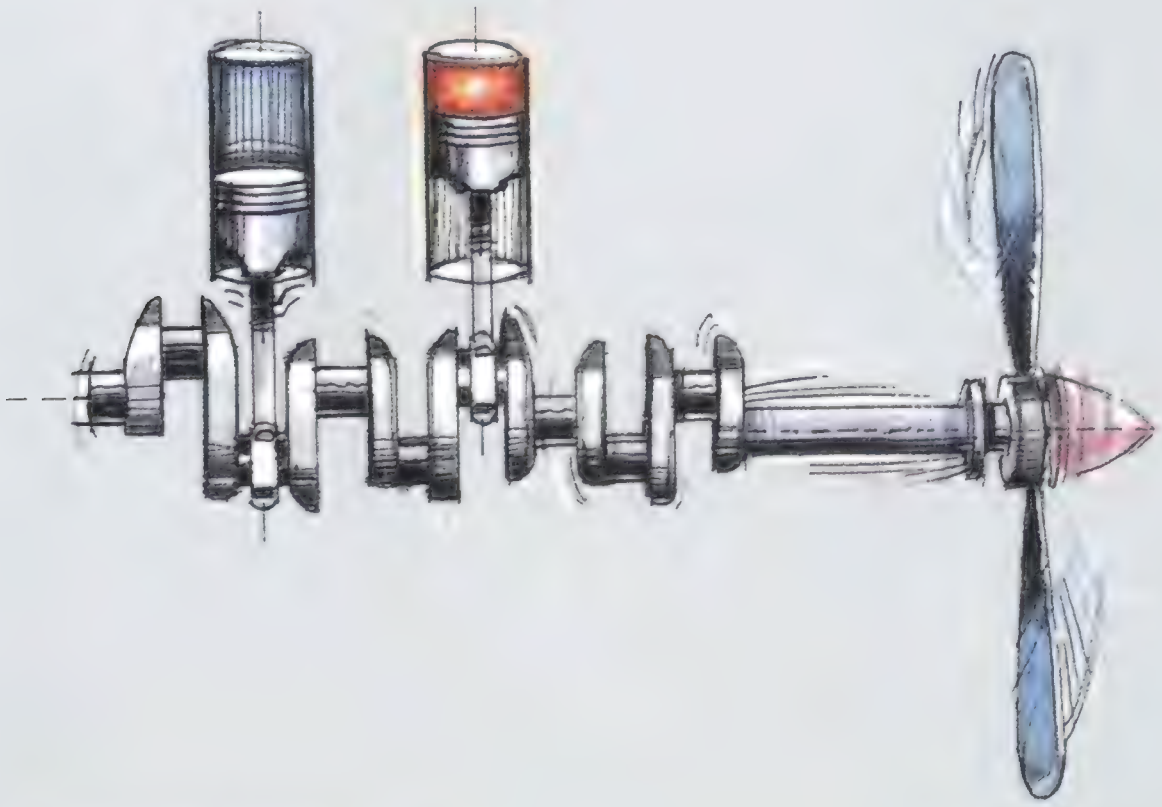


Figure 2 *The force created when combustion occurs in the cylinder also twists the crankshaft of an airplane engine. But in this case, the propeller blade may actually amplify the pulse by "ringing" at the same frequency and imparting a twist in reaction that travels back down the crankshaft. The propeller blade can flex along its length, and its center of mass is at a considerable distance from the propeller hub, an ideal combination to create a vibrating system.*

FUNK WITH FORD MODEL B ENGINE (NASM)

Classical Gas: Car-Powered Airplanes

Charles Van Auken's Ford Model T-powered flyer experiment of 1909 ended at an altitude of eight feet when the crankshaft broke and Van Auken landed in a tree. Bernard Pietenpol seized the baton in 1930 with the Air Camper, a two-seat wooden monoplane powered by a 40-horsepower Ford Model A engine. A simpler version called the Sky Scout was one of the first successful amateur-built designs. This single-seater used a 30-horsepower Model T engine and could be constructed from $200 worth of materials.

One of the first fully certified examples was the Wiley Post A, named after the famous aviator and the craft's powerplant, a Ford Model A engine. About a dozen were produced during the 1930s. Later, the Funk B2 used an aluminum-block version of the same engine in 330 production two-seaters.

Studebaker got into the act in the mid-1930s by backing the Waterman Arrowbile, one of the first flying-car attempts. Waterman was one of thirty respondents to the 1933 Vidal competition, a U.S. Bureau of Air Commerce program to stimulate low-cost aircraft development. To qualify for a type certificate a 100-horsepower Studie six was run for 150 hours under load. It passed that test with flying colors but only five craft were built before the program ended.

Another Vidal proposal, the SF-2 Plymacoupe, used a Plymouth six-cylinder engine driving a propeller at half speed through a bolt-on gear reducer. This 900-pound aircraft was capable of cruising at 85 mph.

One of the most successful Vidal-inspired airplanes was the Arrow Sport F, which used a modified Ford flathead V-8 producing 82 horsepower. After World War II, Mooney Aircraft certified the single-seat M-18 Mite with a 22-horsepower Crosley four-cylinder engine. Ten airplanes were built, all subsequently repowered with aircraft engines due to a lack of faith in the Crosley's crankshaft.

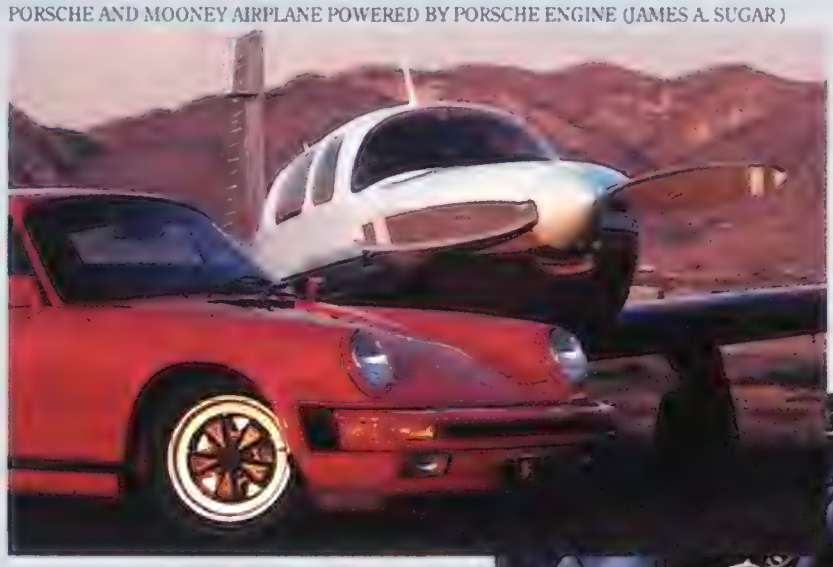
The success of the Volkswagen Beetle prompted U.S. car makers to respond with their first wave of small cars—the Chevy Corvair, Ford Falcon, and Plymouth Valiant—in the early 1960s. When Buick introduced a light, compact V-8 with an aluminum block and cylinder heads in 1963, the Cessna Aircraft Company deemed the engine worth a try. Test flights were successful but they led nowhere.

That didn't discourage amateur builders who, by the late 1960s, found salvage yards well stocked with engines far more suitable for their use than the classic big cast-iron American V-8s. There were Beetle and Corvair engines with at least three key design characteristics in common with a proper aircraft engine: cylinders arranged in a flat configuration, air cooling, and light-alloy castings for major components.

Fred Geschwender of Lincoln, Nebraska, experimented with various Ford V-8 engine conversions throughout the 1970s and again more recently. One of his discoveries was that a heavy flywheel in combination with a chain-driven speed reducer and belt-driven accessories combined to reduce torsional vibration problems. Ultimately shut down by the FAA, this self-made engineer identified a demand for affordable horsepower capable of replacing not only the old radials but also the new turbines in the agricultural airplane field. Another entrant in the same market was Joe Schubeck, whose Stage II engine was derived from a drag-racing block based on the Chrysler Hemi. Schubeck's engine flew on a Grumman AgCat.

The Porsche-Mooney project of a decade ago suffered from a different problem: not enough customers. In engineering terms, the conversion of a Porsche 911 engine to aircraft duty was a complete success. It passed muster with the FAA while demonstrating a few distinct advantages: reduced cockpit noise and the convenience of a single-lever electronic control system for engine speed, fuel-air mixture, and propeller pitch. The use of an engine-driven fan keyed air flow to throttle setting, thereby avoiding a standard aviation-engine bugaboo—shock cooling. Porsche had plenty of aircraft experience, having previously configured the same engine as a ducted fan for a blimp. The downside was diminished performance versus the standard Lycoming engine and a high price resulting from unfavorable swings in the currency-exchange rate. After selling only 46 units, Mooney shelved its Porsche-engine project.

PORSCHE AND MOONEY AIRPLANE POWERED BY PORSCHE ENGINE (JAMES A. SUGAR)



PORSCHE ENGINE (JAMES A. SUGAR)

COURTESY DICK MacCOON

The Thunder engine endured about 20 hours of test flying on the port side of the Aero Commander at left, but even the stresses of racing in a Can-Am sports car (below) were mild compared with aircraft duty.

pound package only 60 percent as bulky as the equivalent 300-horsepower Lycoming aircraft engine. (Two mass and volume contributors—the Cadillac's coolant and radiator—are excluded from this comparison.) The Northstar's weight and power rating look attractive for aircraft until you look at what it's asked to produce on the road. A mere 30 horsepower from the Northstar will propel a Cadillac at 65 mph all day long. The remaining 270 horses under the hood are rarely used, and at full throttle the car will accelerate from zero through the 100-mph barrier—the felony zone for speeding tickets—in a mere 20 seconds. But just to make sure the Northstar is tough enough to deliver more than 100,000 miles of faithful service, GM engineers devised one of the auto industry's most grueling durability tests. On a test stand, with a power absorber connected to the engine, the Northstar was run for 300 hours at full throttle, with the load being controlled on a schedule that allowed the engine to run at speeds that ranged between peak torque and peak horsepower.

In the world of aircraft, though, that's child's play. An aircraft engine typically runs more than a minute at full throttle during every takeoff. Even throttled back for cruise, an aircraft engine must deliver 60 to 75 percent of full rated power for hours on end. And while 300 hours was typical for engine life in wartime and still adequate for experimenters, owners of new light aircraft typically expect 2,000 hours of service before a major overhaul.

The duty cycle is much more strenuous for an aircraft engine because of two aerodynamic forces—lift and drag. Drag rises with the square of velocity, and light aircraft typically cruise about twice as fast as an automobile. Furthermore, the engine power needed to overcome that drag is proportional to the cube of the velocity. Let's use the Cadillac as an example again: if 30 horsepower is enough to maintain a 65-mph cruising speed, it takes approximately 240 horsepower to propel the same car at 130 mph.

Differences in lift forces are also dramatic. Rolling vehicles are supported by the ground and don't need lift. But every 100 or so pounds of lift produced by an aircraft's wing costs the average airplane one to two pounds of induced drag. A typical 3,200-pound aircraft flying at 150 mph consumes 18 horsepower just to overcome its induced drag.

In the end, the aircraft engine and the car engine are so different because their duty cycles necessitate differences in design, which lead to different economics. Engineering them is a fine art of determining a cylinder wall thickness here or a bearing width there so that the final product delivers just enough performance and durability without being too heavy, bulky, or expensive. Bearing dimensions and coolant flow rates that work just fine for 300 horsepower in momentary bursts are inadequate when that same output must be delivered continuously.

Aside from the marked differences in their duty cycles, the two engines also work in completely different environments, and while both powerplants must be engineered to handle the internal vibrations caused by irregular combustion forces and the inertia of pistons and connecting rods flailing around inside, the aircraft engine, which is attached to a propeller rather than a drive shaft and two wheels, operates under far more severe circumstances (see "Why an Airplane Is Not Like a Car," p. 75). Despite the fact that they start out looking so much alike, after you list the many differences, you begin to wonder whether the engines really have anything in common. In the 1970s, a small company in California mounted a serious attack on the problem of applying automotive propulsion to aircraft. And despite the legions of experimenters and engineers who had gone before them, they would discover that they were starting from scratch.

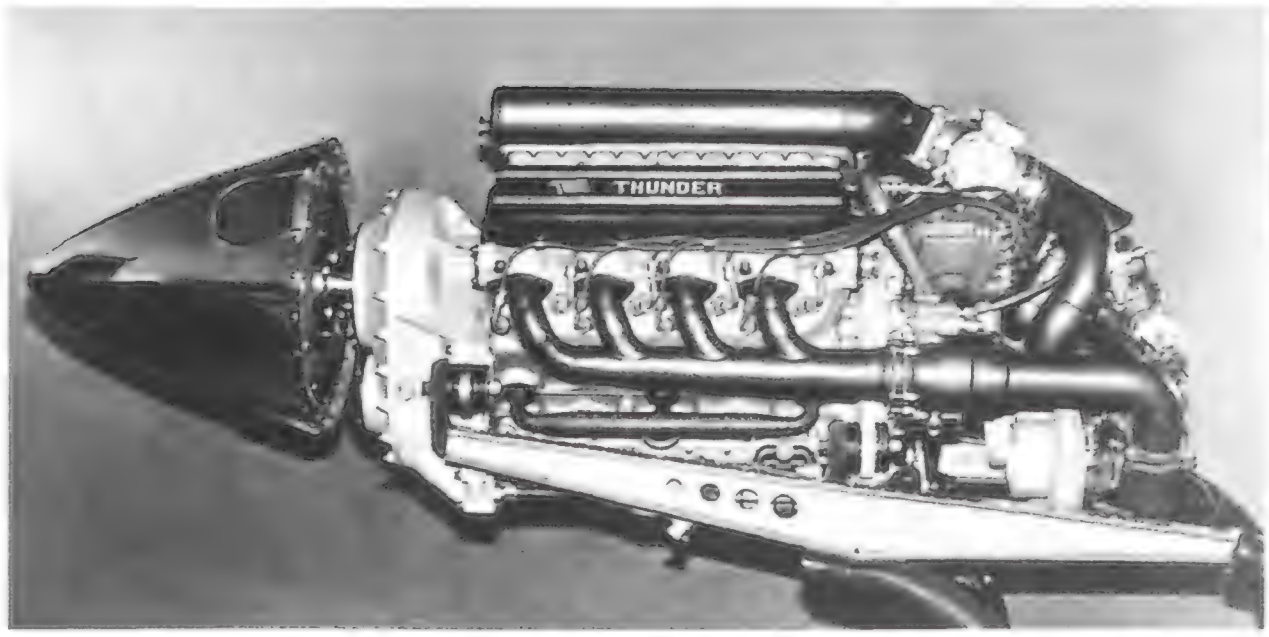
The Aero Commander won its early fame and reputation when it was entrusted with the life of a U.S. president: Dwight D. Eisenhower used one to commute to his Gettysburg, Pennsylvania farm. Richard MacCoon dates his affection for the airplane to a flight with his brother Grant in one of the big high-wing twins. He liked the airplane

DAN PATTERSON

so much he began to work on improving it with systems such as air conditioning and turbocharger packages. He also began looking around for bigger engines. What MacCoon wanted fell in the gap between the largest piston engines and the smallest gas turbines. "We were constantly after Lycoming or Continental or anybody to build a bigger engine that would fill that 400- to 800-horsepower category," he says.

When the engine makers didn't respond, MacCoon and his brother formed Thunder Engines, but instead of creating an engine from whole cloth, they began looking outside of the aviation industry for an engine they could adapt. And the search began in a familiar community: the world of auto racing. "We didn't have the expertise to reinvent the wheel," MacCoon says, "but we did know about a joint effort between Reynolds Metals and General Motors to develop a big aluminum V-8 for Can-Am [Canadian American Challenge Cup] racing." The Can-Am series peaked in the early 1970s and featured big racers with enormous V-8s, which, in turbocharged form, generated more than 1,200 horsepower.

MacCoon rented a performance shop that had closed after the Can-Am series folded, and he parked an Aero Commander at a nearby airport. Then he hired Douglas Meyer, a jack-of-all-trades who had worked on the Can-Am cars and knew the engines well. "As race car guys and as hot rodders...it didn't seem to be that mystical." Meyer recalls. "I was running up against airplane guys, and they would say 'You can't do that; those engines won't work. You've got to have slow-turning engines, you've got to have big, beefy parts, you've got to have air cooling,' and the stuff you don't gotta have." To prove it could be done, MacCoon and his crew began to adapt one of the Can-Am racer engines for installation on the Aero Commander.



COURTESY DICK MacCOON

The Thunder (above) and the Orenda (right) look like mirror images, but there is no "car" left in the Orenda version, as aerospace suppliers have replaced the automotive racing parts suppliers whose products MacCoon relied on for the original version.

That was no small task, as two gearboxes had to be engineered, the more formidable being a reduction unit to drive the propeller. Late in the game, after the engine had already been installed, a major problem arose. It turned out that aircraft and automotive engines rotate in opposite directions, and the propeller was pushing instead of pulling. The expedient fix was a Hartzell propeller designed for pusher applications; bolted to the Can-Am engine, it pulled.

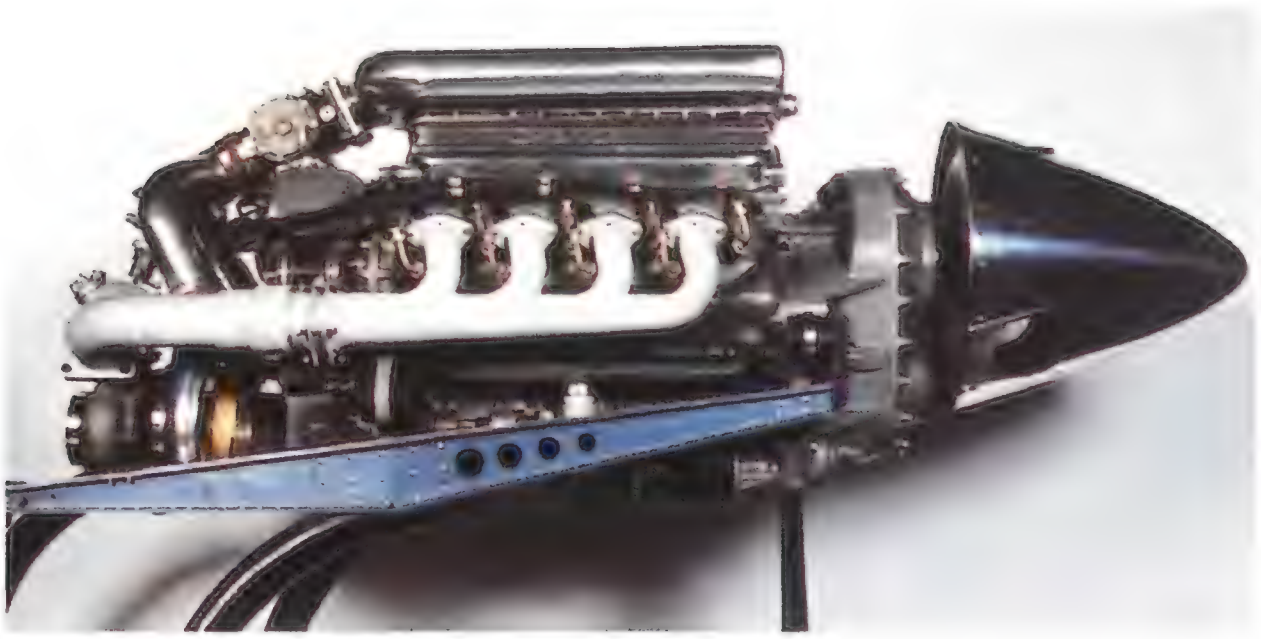
For its maiden flight, the engine was tuned to produce 550 horsepower with a single turbocharger to match the output of the standard Garrett AiResearch turboprop on the opposite wing. To cool the piston engine, MacCoon's crew installed a huge car radiator in the aft fuselage, fabricated air inlet and outlet ducts, and ran coolant lines connecting the radiator and engine along the outside of the fuselage, covering the plumbing with a simple fairing. MacCoon remembers that first day in the air some 15 years ago as if it were yesterday: "The engine's throttle response was phenomenal," he says. "I could yank the lever up and down—something you can't normally do with aircraft engines—and it would reach full power in less than two seconds. In fact, the throttle response was so immediate that it controlled the yaw of the plane much better than the rudder pedals.

"On the takeoff roll, I said to myself *This is absolutely incredible* because our engine was as smooth and responsive as an electric motor," he recalls. On a later flight, they shut down the turbine and ran the prototype up to full power.

"All the vibration suddenly left the airframe," MacCoon says. "At first we thought both engines had stopped, but that wasn't the case at all. Pilots consider turbines super smooth, but they're not. Spin any piece of machinery at 36,000 rpm and you're going to get a

ENGINE SPECIFICATIONS

MANUFACTURER	WRIGHT BROTHERS	ROLLS-ROYCE
MODEL	1903 FIRST FLIGHT ENGINE	GRIFFIN 60 SERIES
Configuration	4-cylinder inline	V-12, supercharged
Supercharged/turbocharged	no/no	yes/no
Cooling	liquid	liquid
Displacement, cubic inches	201	2,239
Bore x Stroke, inches	4.00 x 4.00	6.00 x 6.60
Horsepower @ rpm	16 @ 1,200	2,035 @ 2,750
Torque @ rpm, foot pounds	70@ 1,200	3,886 @ 2,750
Piston speed @ redline rpm, feet per minute	800	3,025
Brake Mean Effective Pressure @ peak torque, pounds/in²	52.5	311.3
Crankshaft main bearing area, in²	39.5	122.0
Weight, pounds	180	2,090



COURTESY ORENDA AEROSPACE CORP.

lot of high-frequency vibration. But our engine was carefully balanced and spinning at only 4,400 rpm so it felt perfectly smooth and quiet." When they were done, MacCoon had flown the airplane for almost 20 hours.

The next task he faced was upgrading the engine to endure an aircraft duty cycle. The crew pulled the V-8 out of the airplane and mounted it on a dynamometer, where full loads could be applied safely and methodically for hours on end. Then they began making changes: The lower portion of the block was extended to stiffen the portions that support the crankshaft. To increase cylinder size and gain torque, they raised the upper surface of the cylinder block, increasing the "deck height." To make room for dual spark plugs (standard on aircraft; if one ignition system fails the engine will continue to run), they redesigned the cylinder head and relocated the valves. Virtually every component was upgraded to tougher materials and larger bearing surfaces.

Redesigning the original Chevrolet-Reynolds engine was frightfully expensive. Forging dies to hammer out new crankshafts cost $100,000. MacCoon admits spending $4.5 million in 28 months on the task, and even after the engine was upgraded, it still had to prove its durability. MacCoon notes that the team spent $2.5 million in one year stretching the engine's life from 7 to 17 hours. He says the engine never blew up, but signs of excessive wear were everywhere. When he finally realized they had "Peter-principled" themselves, he called in outside assistance.

First MacCoon coaxed former engineer Bob Earnest out of retirement. Earnest reached the 20-hour mark before he fell ill and had to abandon the program. MacCoon turned to a second friend, John Beck, who had worked for a diesel engine manufacturer. After examining valves, bearings, pistons, and piston rings like a paleontologist studying bones, Beck proclaimed, "Your pistons are in serious distress. You don't have a 600- or 700-horsepower engine by any stretch of the imagination." According to Beck, MacCoon had a 500-horsepower engine with a 500- to 1,000-hour service life. "And this is after two and three years and millions of dollars in this program—$10 million to be exact," MacCoon says. "I didn't want to hear this from someone of his caliber."

MacCoon was crestfallen, but Beck assured him he had fixes. To cool the pistons, he used a technique common in the world of diesel (and aircraft) engines: a stream of oil squirted at the bottom of each piston to carry away heat. He called for more robust pistons, thicker rings, broader valve seats, and a different valve guide material—design changes aimed at ushering heat away from the hard-working parts.

Beck's changes took another six months, but the first durability test proved that they had worked: Piston temperatures plummeted 98 degrees, only two degrees less than his calculations had predicted. With internal temperatures under control, durability was in hand. Armed with that news, MacCoon thought the establishment might finally be interested in his project. He contacted every major and a few minor engine producers in search of the money necessary to take the next steps—Federal Aviation Administration certification and production. But no one was interested in sharing the cost. When MacCoon's funds petered out in 1987, he put his project in storage.

In 1989, Toyota introduced an all-aluminum, dual-overhead-camshaft V-8 to power the Lexus LS 400 luxury sedan. At the same time, engineers in both the United States and Japan began investigating aviation applications for the Lexus engine. Hamilton Standard was tapped to assist in the development of a suitable propeller and a single-lever electronic control system to manage throttle position, air-fuel mixture, and propeller pitch. Called FADEC (full-authority digital engine control), such systems are common in turbine applications, but the company says this was the first appli-

WRIGHT AERONAUTICAL	GENERAL MOTORS	ORENDA	TEXTRON LYCOMING
R-3350, CYCLONE 18	CADILLAC NORTHSTAR	600	IO-540-K
18-cylinder twin row radial	V-8	V-8	horizontally opposed 6
yes/yes	no/no	no/yes	no/no
air	liquid	liquid	air
3,348	279	495	542
6.12 x 6.31	3.66 x 3.31	4.44 x 4.00	5.12 x 4.38
2,200 @ 2,800	300 @ 6,000	500 @ 4,200	300 @ 2,700
4,127 @ 2,800	295 @ 4,400	625 @ 4,200	584 @ 2,700
2,946	3,586	2,933	2,067
185.9	159	190	163
n/a	29.2	55.6	65.3
2,780	400	753	470

cation to a reciprocating engine.

After testing both here and in Japan, the FAA issued a type certificate on December 21, 1995, for Toyota's FV4000-2TC 350-horsepower twin-turbocharged V-8. A probe of the market is currently under way to determine if anybody out there is interested in buying such an engine. Even if no one is interested, Hamilton Standard plans to apply for a production certificate.

But don't get out your checkbook just yet. Even though the engine has an FAA certificate and will have production approval, neither Toyota nor Hamilton Standard has announced plans to begin making engines—which, for the moment, leaves the field open. Enter Dick MacCoon. Again.

In 1994 he succeeded in finding a patron for his Thunder Engine project in the Orenda Division of Hawker Siddeley Canada, a turbine engine component manufacturer and overhaul center. Early in 1996 Orenda was sold to Fleet Aerospace of Fort Erie, Ontario. Orenda got one Thunder V-8 engine nearly ready for certification while MacCoon kept all future rights to install Orendas on his beloved Aero Commander twins.

But Orenda didn't just dust off MacCoon's blueprints and send his V-8 to production. The aviation world had progressed during the years the engine was in storage, so the design needed updating. For one thing, practically every component will come from aerospace suppliers, not automotive vendors. Notes Orenda's chief engineer, Larry Shiembob, "This is a true aerospace engine now. This is not a converted automobile engine. We created our own 'murder' cycle and identified a valve spring problem during a hundred or so hours of durability testing. That problem has been solved with a new material and slight changes in the camshaft. To log a thousand hours on our durability engine, we hired a dynamometer testing firm to run one around the clock."

And there are tall hurdles to clear for FAA certification. During the torsional vibration test, engineers monitor how well the crankshaft handles strain when the engine is run on seven cylinders. Other studies address detonation ("knock") resistance. Connecting rods have withstood 10 million cycles of loading applied by a test fixture.

Meanwhile, independent modifiers are working on adapting the engine to the Beech King Air and deHavilland Canada Beaver, among others. While Orenda negotiates with

PAUL BOWEN PHOTOGRAPHY

JAMES A. SUGAR

COURTESY STAR KRAFT

Orenda's target is the PT6 turboprop, which powers the Beech King Air (above), but the company has made offers of sample engines to experimenters. The auto-powered Pond Racer (left), lost in a crash, could have used a pair. Star Kraft's tandem twin (below) is a candidate for an Orenda if the airplane can get into production. It may be only a baby Merlin, but an Orenda at full cry will sound as sweet (right).

airframe makers to nurture interest in using the engine in newly manufactured airplanes, the focal point of the market seems to be in replacing overhauled turbines in existing airframes. Over 25,600 Pratt & Whitney Canada PT6 engines had been delivered by mid-1996, and Orenda believes that when their service life finally ends, some portion of the fleet can be re-engined with a new product. It can run to $300,000 to overhaul a pair of PT6s, more than some of the airplanes they are mounted on are worth.

Shiembob concedes that a new 500-horsepower Orenda engine costs about the same as a PT6 overhaul, but he insists it's still a good deal: Orenda claims lower fuel consumption, more power at altitude for a higher cruising speed, and better climb. "Our engine provides 500 horsepower continuously up to 25,000 feet, while PT6 output has dropped off to 300 horsepower at that altitude," he says. "The major payoff occurs at the next overhaul point. The turbine pilot faces the same $200,000 or more cost. But the Orenda V8 pilot will be able to rebuild both his engines for $50,000." It remains to be seen whether Orendas are durable enough to compete with the PT6, one of the most reliable engines ever built: one PT6A-20 engine has gone 15,000 hours between overhauls, and one maintenance program offers 8,000 hours of service life. Even if an Orenda runs for only 2,000 hours and requires four overhauls to the PT6's one, it could still break even under such a scenario, but the aircraft operator would have to accept more time in the repair shop. And the Orenda runs on aviation gasoline, which may become a scarce commodity as the worldwide market for it shrinks.

Initially, Orenda is planning on sales of 100 to 200 engines per year—that's less than one percent of the global PT6 market. The effort to certificate a modification for the Beech King Air—the airplane flying around with more PT6s than any other type—is already well under way at Merlyn Products of Spokane, Washington. Stevens Aviation, a South Carolina modification shop, recently ordered 140 Orendas destined for King Airs and has exclusive rights to distribute the modification. Crop dusters are the next target. According to Shiembob, "As their old radials wear out, some of them are spending $550,000 to $600,000 to hang a [new] PT6 on their aircraft. The 500-horsepower normally aspirated Orenda we have under development will do a better job for much less."

It's too soon to say whether liquid-cooled piston engines will ever regain their prominence or even that turboprop operators will accept a return to reciprocating power and forgo the trusty PT6 to risk something new and unknown. But Orenda's effort won't be lost on an aviation world hungry for lower operating costs and something different in the sky.

After spending a king's ransom and sweating over a hot test cell for a decade, you'd think Dick MacCoon might begrudge the Orenda logos all over his good idea. He doesn't. As long as he hears that thunder pealing from the exhaust stacks, he considers his mission accomplished. "When I started this program, it wasn't to build an engine, it was to get an engine for an airplane," he says. His father once gave him a motor scooter—or at least a pile of parts from which to build one. There was a lesson in it, he says: "If I wanted something or needed something badly enough, if I couldn't get it, I could build it.... From my point of view, I look at it as somebody taking [the engine] into production, and it's a super-duper deal for the industry, it's going to employ a lot of people, and yeah, indirectly there's kind of a personal satisfaction that I had a part in it....It's something that needed to be done."

COURTESY ORENDA AEROSPACE CORP.

UNITED WE ORBIT

When two giant vehicles meet in space, collision becomes collaboration.

by James E. Oberg

Mission STS-74, November 1995: An IMAX camera in the shuttle cargo bay caught Atlantis *and Mir moments before docking. The shuttle's final approach is always slow, slow, slow—just over an inch a second.*

ALL PHOTOGRAPHS FROM NASA

How a space docking feels can depend on which side of the interface you're facing—whether you're the docker or the dockee. But when the 100-ton shuttle *Atlantis* linked up with the 100-ton space station Mir in June 1995, neither crew had any doubt about what was happening.

Just before contact, with the two spacecraft perfectly aligned, the *Atlantis* crew had pushed a button to fire thrusters that gave them a last nudge into the Russian docking mechanism. For the shuttle astronauts, it was the noise of the thrusters more than anything that signalled their arrival at Mir. "You could hear the booming of the forward jets," recalls Charlie Precourt, copilot of mission STS-71. The contact itself is "absolutely imperceptible," says Kevin Chilton, who commanded the third shuttle-Mir docking mission nine months later. You know something's happening from "all those cannons going off all around you," but there was no bumping or jostling inside the shuttle cabin.

On the Russian side it was a different story.

The impact felt "like a big hug," commander Vladimir Dezhurov recalls. "A real *man's* hug." The Mir began quiv-

Astronaut (and future NASA head) Richard Truly helped troubleshoot minor glitches during the 1975 Apollo-Soyuz docking. Problems with Gemini IX in 1966 were more serious: The docking had to be scrapped when a clamshell-like protective shroud on the target wouldn't open (below).

ering, then calmed down. When the station finally stopped shaking, says Dezhurov, "we understood the docking had occurred."

Over on *Atlantis*, where shock absorbers in the docking system dampened the force of impact, the mechanism "bounced like a baby carriage," Precourt says, but the back-and-forth motion was too subtle to be sensed directly. "The only way we could tell there was any rebound at all was to look in the camera."

The first orbital hook-up of U.S. and Russian spacecraft in two decades had come off without a hitch.

Docking has been part of the spaceflight repertoire for more than 30 years, and as often happens, NASA has made a complex and challenging operation look boring and routine. In practice it is anything but. Robert "Hoot" Gibson, who commanded *Atlantis* during the first shuttle-Mir mission, calls space docking "a cross between air-to-air refueling and a carrier landing." When the two spacecraft are still at a distance, it seems easy. "But the closer you get, the tighter you control, and the smaller the allowable errors can be," he says. With an unlucky combination of equipment problems and human error, things can go spectacularly wrong, and that's reason enough to regard each space docking with apprehension and respect.

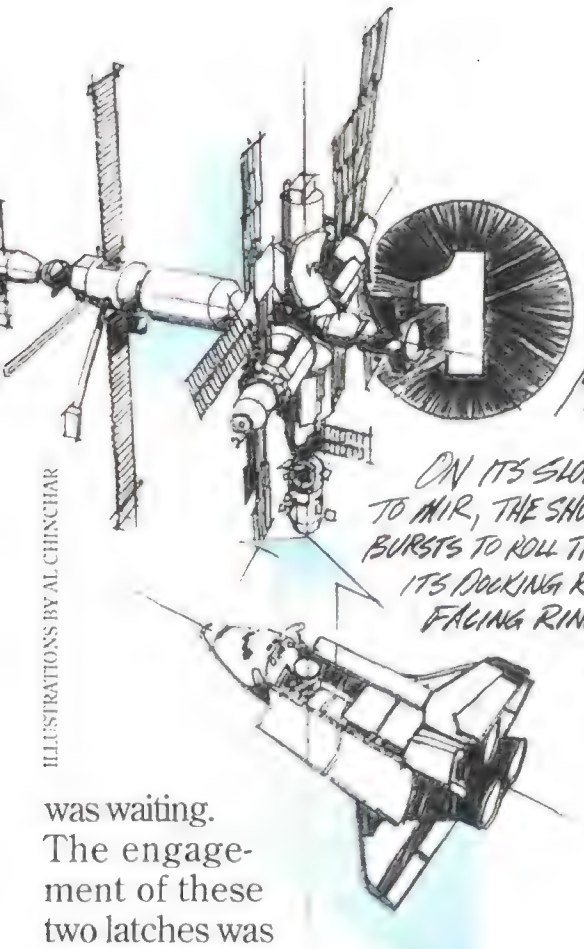
When Neil Armstrong completed the world's first orbital docking, connecting his Gemini VIII capsule to an Agena target vehicle in 1966, his joy was soon overshadowed by a life-threatening out-of-control tumble that led to an emergency splashdown in the Pacific (the fault lay in a stuck thruster on the Gemini, not in the docking technique). On the very next flight, a shroud covering the target's docking port failed to open fully, making docking impossible.

Docking problems frustrated Russia's first space station mission in 1971 and nearly aborted NASA's first Skylab mission two years later. When the Russians added the Kvant science module to the Mir station in 1987, an errant trash bag got stuck in the docking interface, preventing an airtight seal until spacewalking cosmonauts removed it. Other failures and close calls convinced both U.S. and Russian space engineers that nothing about space docking would ever become routine.

Bumping two large masses together in orbit without damaging or breaking anything makes for a tricky physics problem. Vehicles docking on Earth have at least some of their motion already constrained at the time of contact. Freight cars move along rails, ships float on water, even aircraft have aerodynamic stability. But in space, position and orientation can vary in all three dimensions, and can change at different rates. All these variables—Precourt calls orbital docking an "eight-degrees-of-freedom problem"—have to be controlled simultaneously to make sure the final contact happens within the mechanical limits of the docking hardware. On Earth we also encounter natural damping forces—friction, air and water resistance, the restraining forces of rails or cables. In space, all the energy has to be absorbed and damped out within the vehicles themselves.

Because these are problems imposed by the laws of physics, it's no surprise that in the mid-1960s, U.S. and Russian engineers came up with essentially the same design for docking mechanisms. Both countries built systems that worked like this:

The chase vehicle extended a long, stinger-like probe with capture latches at its tip. On the target vehicle was a cone-shaped receptacle. When the tip of the probe entered the wide end of the cone, it was naturally guided to the back, where another latch mechanism

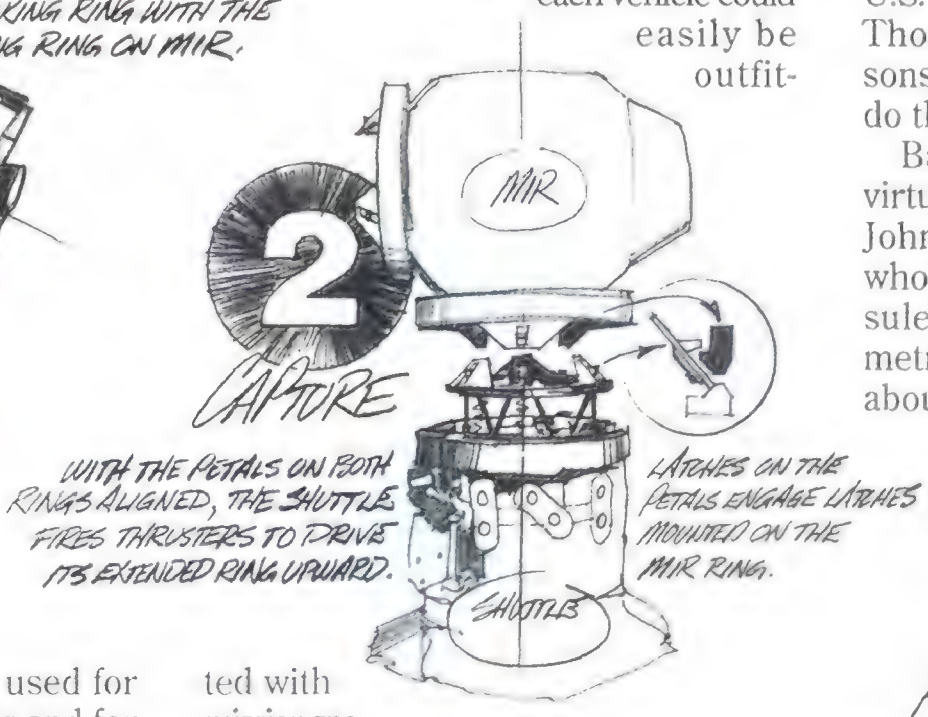


ILLUSTRATIONS BY AL CHINCHAR

was waiting. The engagement of these two latches was called "soft docking." The docking probe then retracted, drawing the two vehicles together so that facing rings could be latched together for a "hard dock."

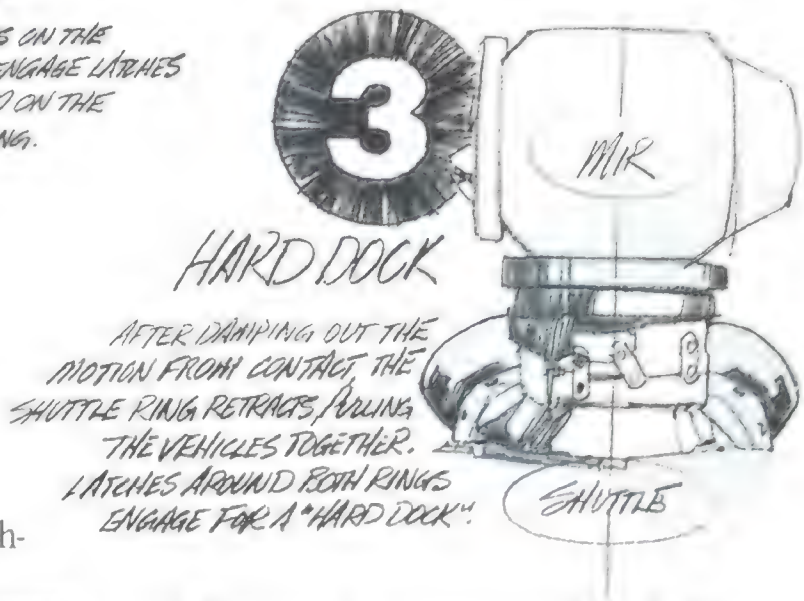
This was the basic design used for NASA's Apollo lunar missions and for the Skylab space station. It also became standard for Soviet vehicles and, with one exception, has served all Soyuz, Progress, and science module dockings with Russian space stations to this day.

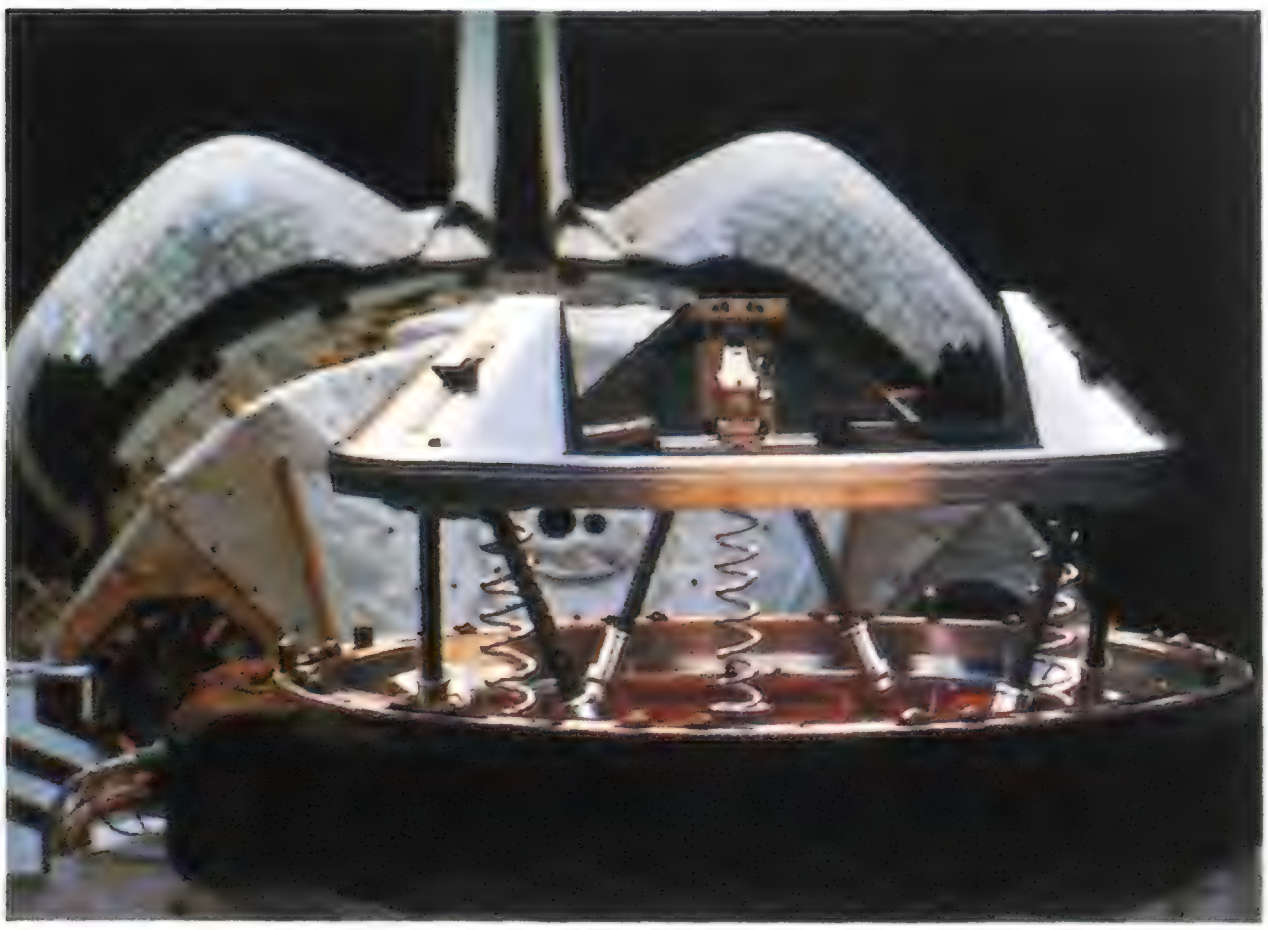
The inescapably "male" and "female" nature of the probe-drogue system has led to countless earthy jests by astronauts and cosmonauts over the years. The major drawback is equally obvious: Only mechanisms of different types can successfully mate. For short spaceflights this wasn't a problem, since each vehicle could easily be outfitted with mission-specific hardware. But engineers knew that at some future point it would make sense to build spacecraft that could dock with any other vehicle in orbit.



The "androgynous" docking mechanism sprang from this anticipated requirement. When Nixonian détente thawed relations between Moscow and Washington in 1971-1972, the resulting plan for the symbolic Apollo-Soyuz orbital docking gave space engineers the opportunity to build and test an androgynous docking mechanism. The new design had an immediate political advantage: Neither the Russian nor the U.S. spacecraft would appear dominant. Though arguably for the wrong reasons, space engineers were enabled to do the right thing.

Based on preliminary sketches by virtuoso spacecraft inventor Caldwell Johnson (a self-made NASA engineer who had co-designed the Mercury capsule in the 1950s), as well as a symmetric ring-to-ring system designed at about the same time in Moscow, U.S. and Russian engineers—led by docking expert Vladimir Syromyatnikov—joined forces and came up with a new design. Each vehicle would have a docking ring with three open "petals" extending out from it. The petals were for alignment only: They fit slot-and-groove style between the petals of the other vehicle's ring, so that the facing rings could fit together only in the prescribed way. During docking, the ring on the active vehicle (complete symmetry was sacrificed) would extend outward on shock absorbers and be rammed (slowly!) into the passive vehicle's ring. The petals would then fit like fingers sliding together, and latches on the active



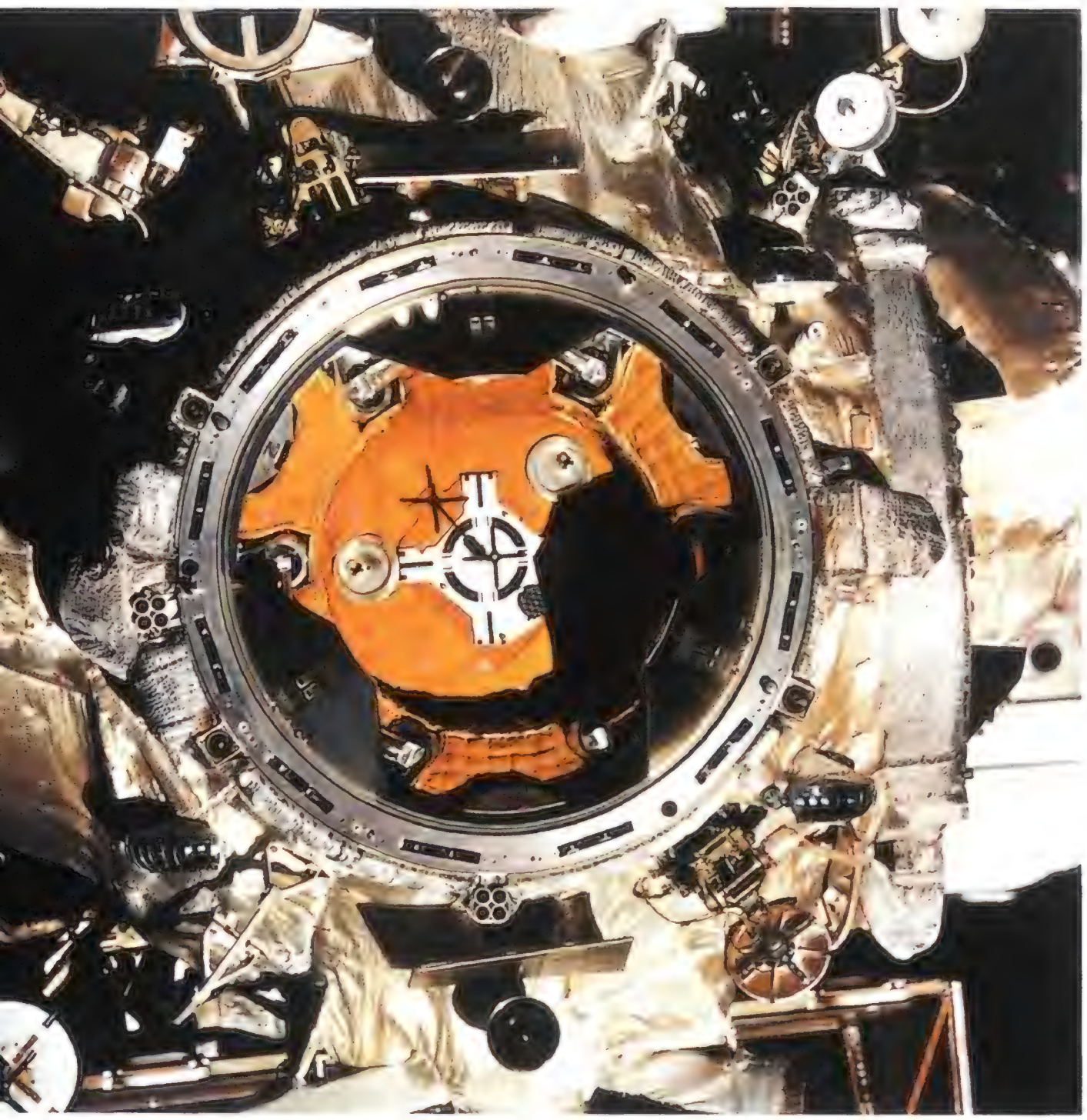


The shuttle's docking ring extends upward from the main docking tunnel for initial capture, then retracts to allow a "hard dock."

vehicle's petals would catch latches on the target docking ring. Finally, after the motion from initial contact was damped out, the extended ring retracted to pull the two vehicles closer together. At that point the heavy latches around both rings would engage to achieve a hard dock.

The new system worked fine on the one mission it flew (Apollo-Soyuz), and its advantages over the probe-drogue set-up immediately became clear. For one thing, the damping mechanism allowed it to handle much more massive vehicles. True, it demanded more accurate alignment from the pilots, but neither pilots nor engineers saw that as a problem.

By the time the Russians were designing the Mir space complex in the mid-1980s, they needed exactly this kind of system for the Buran space shuttle, which was to mate with the station. The shuttles were too massive for the probe-drogue design, and the Russians would now be using a variety of different docking combinations—Soyuz to Mir, Soyuz to Buran, and Buran to Mir. The androgynous system was the only one that could satisfy all these requirements.



The Russians called their design "APAS," for "androgynous peripheral aggregate of docking" ("docking" in Russian is *stykovka*). They improved the Apollo-Soyuz design in several significant ways, most visibly by turning the guide petals inward rather than outward. The system was perfectly designed for the Buran-Mir dockings. But the Russian shuttle was scrapped before the system got the chance to prove itself.

Meanwhile, U.S. space designers had been developing their own docking mechanisms for the shuttle and the Freedom space station. The only principle guiding this complicated, clumsy system seemed to be that it *not* look like the Apollo-Soyuz design. By the

After cinching the shuttle's first space docking, STS-71 Commander Robert "Hoot" Gibson (above) proudly displays the Mir target he'd been aiming for (left). Accuracy counts: The vehicles had to be aligned within three inches.

It's Not as Easy as It Looks

The space docking simulator at NASA's Johnson Space Center in Houston so accurately mimics motion in space, boasted its operators, that some visitors actually get motion sick. Over the previous few months, I was told, two of them had to use the airsick bags hung by the back door.

When I tried it myself, my vestibular system wasn't the only one of my senses that was fooled. The combination of realistic views out the cockpit windows, television scenes, high-fidelity data displays, and the sound of maneuvering rockets firing all convinced me that I really was in control of a 100-ton spaceship heading straight for an equal-sized target. My thumping heart, high-pitched voice, and sweating palms must have been convinced too.

Practice docking runs usually start about 200 feet out, with the shuttle directly below Mir's docking port. The shuttle moves top first toward the station, rising slowly like an aircraft on a carrier elevator. The pilot (me) stands at the aft flight deck, behind the shuttle's two pilot seats. I can watch what's happening through a pair of overhead windows or on two TV monitors displaying the views selected from half a dozen cameras.

I guide the spaceship by gently tweaking two hand controllers, one for moving in any of six directions and the other for rotating. From time to time I adjust the digital autopilot, which maintains certain constant conditions, such as holding the shuttle's orientation steady. I also have a set of laptop computers showing my predicted motion over the next 10 minutes.

Certain rules of thumb apply to any orbital rendezvous. During the last 1,000 feet of climbing up the "R-bar" (the station's radius vector toward Earth's center), the approach speed should gradually drop as the distance to the target shrinks. At 200 feet, I'm down to 2/10 of a foot per second, a genuine "space crawl." At first glance out the overhead windows, the station looks like it's just hanging there. But the lack of motion is deceptive, because very soon things begin happening with startling speed.

At this point you'd better have your alignment right. If the shuttle's docking ring doesn't contact the station's ring within tight margins of speed and accuracy, the latches may not capture properly. Worse yet, the docking equipment could be damaged, ruining the mission. In a truly nightmarish scenario, the shuttle could collide with the station, damaging or destroying both vehicles and putting lives at risk.

The flying skills that ward off catastrophes are honed in simulators like this one. A top-notch space pilot doesn't over-correct, thrashing back and forth on the flight path. Instead, he keeps a running catalogue of soon-to-be-needed changes in all axes of motion, and knows which of them will be accomplished *gratis* by impending maneuvers in other axes. This occurs because the jets on the shuttle aren't pointed strictly in one axis. Using the sideways jets, for example, also imparts a slight roll to the whole vehicle. The result is that some of the sideways motion is real and some is an illusion caused by the rolling motion. A good pilot learns to tell the difference.

The sound of thruster firings is one of the simulator's "user options" and can be toggled on or off. Leaving it on is called "dragon's breath mode" by the operators, who went to great pains to duplicate the muffled howitzer sound of the 900-pound shuttle jets.

"I went to a shooting range and recorded shotgun blasts," one of the engineers told me. "Then we digitized the sound and stretched it out a bit. Crewmen say it's close." At some point he wants to make a recording of a real howitzer to increase the simulator's fidelity.

THE FLYING SKILLS THAT WARD OFF CATASTROPHES ARE HONED IN SIMULATORS.

By the time the station is within 30 feet and the final alignment adjustments have been entered into the autopilot, I no longer have the time or inclination for casual conversation with my hosts. With a sky full of very real looking space station hardware above me and instruments delivering convincing reports of imminent contact, my mind, like that of the man to be hanged in the morning, has become intensely focused.

Pulse, pulse. Small jet firings push the aiming crosshairs on the television screen toward the right, closer to the target painted on the station. Pause, agonize. Do I need a plus-X-axis burn now, or will the vertical trend reverse in time? Is my approach rate right? Mentally juggling all these parameters of motion, I have to decide every instant which ones are okay, which can wait, and which have to be changed *right now*. Dangerously close to cerebral overload, I surf the breaking wave of final approach as the station's docking structure comes in sight out the aft window, only a few feet from contact.

The time for computer displays and digital readouts is past, and only the sight of the looming station fills my senses. I make one final crosswise pulse to center the crosshairs. Just as the petals fit together on their way to contact, I hit the button to fire jets that shove the mechanisms hard enough together to guarantee latching.

The jets boom as the docking rings capture.

There is no further motion or sound.

early 1990s, however, the political winds had changed, and it was no longer unacceptable for Americans to acknowledge Russian space expertise. After a brief review, the Russian system designed for Buran-Mir was adopted for shuttle-Mir and the space station, with Rockwell and RSC Energia doing the modification work.

When Gibson and Precourt were tapped to fly the first docking mission, they knew they were in for a challenge. No space shuttle docking hardware had ever worked properly on its first attempt in orbit. The highly public embarrassments of failed first attempts to dock with the Solar Maximum satellite in 1984 and the Intelsat satellite in 1992 (both of which involved hardware carried by spacewalking astronauts, not vehicles), as well as several less publicized but equally frustrating failures with other space hardware, reminded everyone how easily things could go wrong.

Even after all the hardware had been analyzed and tested piece by piece, experienced engineers knew they weren't finished. At the insistence of veteran space docker John Young, NASA added a special program for "end-to-end testing" at the Kennedy Space Center's Orbiter Processing Facility, where the shuttle is still horizontal. The docking assembly was installed in the shuttle's payload bay with all the flight hardware in place. Test engineers rigged up a mockup of the passive mechanism on Mir and lowered it by crane at docking speeds of only inches per second. They verified in the cockpit that the instrument panel performed as advertised throughout the whole sequence.

One value of these tests was to raise the crew's comfort level with the post-contact damping process, the time between initial capture and hard docking, when the two giant vehicles would be only loosely joined together. During this time, Mir's attitude control system is switched off so as not to introduce

motions that could bend the docking mechanism. But even in this "free drift" mode, the Russians had worried that random twisting of the two large masses might never settle down. Noted Precourt: "This would prevent us from drawing the ring back in."

Based on the ground tests, the crew came up with a solution. Precourt explains: "We interrupted the auto[matic] sequence at the first point we saw ring align, stayed there about a minute, waited until motion stopped, and then we retracted." With the rings on Mir and the shuttle perfectly parallel, the hard dock could proceed.

Even though their hardware was different, the shuttle-Mir dockers knew they had much to learn from the previous generation of astronauts. Precourt spent time chatting with six-time spaceflight veteran John Young, now a special assistant to the Johnson Space Center director. Precourt was especially interested in the difference between simulation and reality. "In a simulator, a lot of the sensations aren't there, but in flight you are subject to a lot of distractions," he says. Young told him to trust the simulators, which was good advice—the crews who've docked with Mir say they are extremely faithful to the actual experience. If anything, says Precourt, the real flight "was a lot smoother than most of the sims, in terms of everything working."

Before mission STS-71, the astronauts "flew" over 200 approaches in a variety of simulators. Docking with Mir requires a very slow closing speed—barely more than an inch per second during the final approach. It also demands great precision. The docking rings have to be parallel within two degrees in each axis, and the targets have to be aligned within three inches of each other. The astronauts have various tools to help them measure the alignment. A metal "stand-off cross" extends on a rod above and parallel to a black painted cross on the Mir target. If the crosses appear in TV views to line up perfectly, the pilot knows he's on track. The TV cameras also have grid markings to make it easier for the astronauts to check their alignment.

Docking is more than a one-person job. Looking through the shuttle's overhead windows, Linda Godwin checks the range to Mir during approach. STS-76 crewmate Rich Clifford later worked outside while the vehicles were still joined in orbit (opposite).

One concern had been the disorienting view caused by the camera's being at a distance from the pilot's eyeballs. "You're not looking at the real world," explains Precourt. "It's not like landing an airplane with a view straight out the front windshield." It's more like closing your eyes, holding your hands out, and trying to touch your fingertips, he says. But even though it took some getting used to during training, it turned out not to be a problem.

Gibson and Precourt, as well as every docking crew after them, learned in the simulators to hit the marks every time, even when jets and instruments and computers failed. On the STS-71 docking, the angular errors were measured in tenths of degrees, almost too small to be noticed. The arrival time was nearly perfect too: They were only two seconds off.

Experience has shown that on-time arrival doesn't matter all that much. "I always argued against getting hung up on the docking time as if it were critical," says Kevin Chilton. "I wanted to dock a minute later or a minute early just to show it's not important." He ended up docking "pretty much on time" anyway.

In fact, so far every docking has been a model of precision. "When you think about it," says Precourt, "it's pretty amazing that you'd have two vehicles flying in space that are subject to bending and moving, yet the relative position of the docking ports can be precisely known when we arrive."

With at least five more shuttle-Mir missions planned, and with dockings to the international space station scheduled to begin in 1998, orbital docking is finally becoming, if not routine, then at least no cause for great anxiety. Engineers working on the space station have come up with a few modifications to the shuttle-Mir design but not many. They plan to fine-tune the orbiter's damping mechanism to further reduce the energy transferred to the station at contact. The station also will have a few of the old-style probe-drogue ports, since a variety of Russian, American, European, and Japanese vehicles will have to dock with it.

Dockings have now taken place with four different configurations of the shuttle and Mir (approaching the Russian station, with all its protruding solar arrays, modules, and vehicles, is "like docking with a porcupine," says STS-79 commander Bill Readdy). The STS-74 crew brought up a new docking module to attach to Mir last year, which provides greater flexibility and places the docking interface at a distance from the main station. This addition, plus the station's different configuration and greater mass, may account for the fact that Mir crews are now feeling less of a jolt than Dezhurov and his companions experienced. Readdy says that when *Atlantis* pulled up to the docking port last September, Shannon Lucid and her cosmonaut crewmates hardly felt a thing.

The STS-74 astronauts even came up with a soundtrack to accompany all the slow, graceful maneuvers in space. A Strauss waltz had already been appropriated by Stanley Kubrick, and besides,

it evoked Vienna, not Moscow. So Ken Cameron and his *Atlantis* crew went with Tchaikovsky's "Swan Lake" for their final approach and docking.

Precourt is now back in Houston training to command another Mir rendezvous mission; he will be the first astronaut to make a second such docking. On his first trip to Mir he spent time with his cosmonaut hosts inside the attached Soyuz spacecraft, and he has been through the complete cosmonaut training program for Soyuz dockings to Mir. As it stands, he has the inside track to become the world's most experienced space docker.

Still, he keeps worrying about what could go wrong, what might be done ahead of time to reduce the risk, and what he might have to do should an unforeseen problem arise in orbit. His biggest fears are shuttle failures that could cause a sudden increase in closing speed during final approach. He's also thought out another failure scenario. "I've told folks that I really think we're going to see a bounce-off," he says. "At some point there's going to be a mechanism that doesn't work for us right. The Russians have had it happen to them." He pauses thoughtfully. "I hope we're adequately prepared to deal with that."

GEORGE HALL CHECKSIX

>SIGHTINGS<

Photographer George Hall traced the path of Sean D. Tucker's evanescent nighttime performance with a three-minute exposure at Miramar Naval Air Station in San Diego last August. Compared with his daytime routine, Tucker's six-minute night show includes a gentler series of aerobatics and calmer music. His crew spends five hours equipping his highly modified Pitts with 120 pounds of racks and pyrotechnics, which Tucker ignites from the cockpit. "The pyro is so bright we have to remove the canopy for the flight to get rid of all the glare," says crew chief Brian Norris, which means that Tucker flies open-cockpit. He looks straight ahead to avoid being blinded by the Roman candles and strobes on the wingtips.

Night performances seem to be on the increase. Even the Blue Angels participated at Miramar by making a showy jet-assisted takeoff in the team's C-130 at dusk.

Bathing Beauties

Battleship and Cruiser Aircraft of the United States Navy, 1910–1949 *by William T. Larkins. Schiffer Publishing, Ltd., 1996. 208 pp., 400-plus b&w photos. $49.95 (hardcover).*

This unusual photo-essay is about a bygone era of naval aviation, 1910 through the 1940s. Few examples of the old floatplanes from this period remain, and the ships—sleek, majestic, and menacing in the book's extraordinary images—are lost forever, sunk in the battles of the South Pacific, relegated to the scrap heap, or preserved in mothballs to await another call to action.

Through some 400 rare and remarkably clear images, the author has re-created the entire spectrum of floatplane operations. He brings alive a strange world of catapult launches off mammoth gun turrets, aircraft recovery operations staged while the ships were under way, and a way of life incomprehensible to the ship-based scout pilots' land-locked brethren. Servicing, maintenance, and repair of airplanes were performed under conditions of extreme crowding and clutter. Fragile aircraft routinely stored on the open deck were exposed to wind and weather, corrosive stack gases, salt spray, and embers from ships' smoke stacks and incinerators, making fires an occupational hazard.

Few scout/observation pilots ever forgot the exhilaration (or stark terror) of a catapult shot from the top of a 16-inch gun turret at night. Equally memorable were recovery operations, in which a fortuitous combination of excellent seamanship, exquisite timing, and good luck often made the difference between a successful recovery aboard ship and misfortune. The radioman in the rear seat had the unenviable job of attaching the aircraft recovery cable to the ship's crane, and wingtip floats were routinely damaged. Capsizing and sinking were common. Standing on the wing or fuselage as the airplane was hoisted to the safety of the ship's weather deck was obviously not a job for the faint of heart, and in the process, aircrewmen displayed considerable agility and an occasional flair for the dramatic.

The captions are essential to the complete story, serving to hold the book together. They are a treasure trove of facts, lore, and trivia about aircraft markings, paint schemes, and aircraft histories. The author's observations on the composition of each photograph present the reader with a unique opportunity to learn about a way of life on a man-of-war during a time when man and machine were learning to coexist under the most difficult conditions.

Complementing the text and illustrations are appendices loaded with an assortment of tables that reflect the vast amount of statistical data available to the serious researcher. There is enough to please the most avid trivia buff and pique the curiosity of the casual reader. To the reader jaded by a steady diet of sophisticated warship and aircraft electronic wizardry, this book will be a welcome relief and a wonderful opportunity to explore a little-known or -understood part of aviation history.

—Tim Wooldridge is a former naval aviator and a curator at the National Air and Space Museum.

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Double Fighter Knight *by Ilmari Juutilainen. Apali Oy (distributed in U.S. by Motorbooks), 1996. 255 pp., b&w photos, maps, and glossary. $42.95 (hardcover).*

In a northern corner of World War II, tiny Finland fought two bitter campaigns against the Soviet Union—and didn't do too badly either. All the Russians got out of it was the land bridge between Lake Lagoda and the Gulf of Finland, which they hold to this day. During the first campaign, Stalin was Hitler's ally, so the United States let Finland buy 44 fighters of a type known and scorned in the West as the Brewster Buffalo.

Flown by men like Sergeant "Illu" Juutilainen, the roly-poly U.S. Navy fighter was credited with an incredible 32:1 kill ratio over the Red Air Force. "Fat hustlers, just like bees" is how Illu remembers them. "They had speed, agility and good weaponry too." The second Russian-Finnish battle was triggered by Hitler's decision to attack Russia, thus making Finland an Axis partner and Illu a Messerschmitt pilot.

The Finns went to Germany to pick up their Bf 109s. Hitler reciprocated by visiting Finland's Immola Air Base. Illu was credited with 94 victories and twice won his country's highest honor, the Mannerheim cross, making him the "double knight" of the title.

All together, this is a dandy read for anyone who dotes on lost causes and doughty warbirds.

—Daniel Ford wrote "The Sorry Saga of the Brewster Buffalo" (June/July 1996).

Human Error *by Tom Casey. St. Martin's Press, 1996. 265 pp. $21.95 (hardcover).*

Pilot meets pilot and they fall in love. Pilots crash airliner and lose licenses. Pilots get licenses back. A predictable plot and one-dimensional characters make this a novel for those without discerning literary tastes.

But when the author, a pilot, writes about airplanes and airline culture, his writing turns articulate and fluid. And he doesn't spare the jargon; in fact, *Human Error* becomes a sort of "E.R." of the jet-afflicted. Things begin to pick up airspeed in the second half, with a few almost intense scenes from an accident investigation inquiry.

I hope Tom Casey keeps at it and writes more books, honing his craft and sticking to subjects he knows. In one respect writing is like flying: You can't learn everything on your first trip out.

—Phil Scott is a frequent contributor to Air & Space/Smithsonian.

Ironclaw *by Sherman Baldwin. Morrow, 1996. 265 pp. $24.00 (hardcover).*

A young Navy pilot has just come aboard the aircraft carrier *Midway*, which is stationed in the Persian Gulf. Just 10 days earlier he had flown his final check ride in an EA-6B Prowler. His logbook lists a total of six night carrier landings, the last one 53 days ago. And his single experience at night refueling was conducted "one minute after official sunset at 20,000 feet"—a very bright night.

Thus this memoir begins, and soon the reader is in the cockpit with Baldwin in his Prowler as he is catapulted into the darkness on his first night training mission. Desert Storm is just days away, and this "nugget" agonizes as he struggles to perform as a war-ready professional for the three experienced ECMOs (Electronic Countermeasures Officers) who are sweating out his first night mission. The ECMOs know he should not be flying. Regulations say pilots who have not had a night landing in the last 20 days must re-qualify. But a war is coming, and the EA-6B is a critical asset. The carrier's attack aircraft will not dare venture into the incrementally deadly airspace above Saddam Hussein's SA-2, SA-3 and SA-6 missile threat rings unless the EA-6Bs are along to destroy the missiles' radar guidance with HARMs—missiles that home in on the radar antennas—or render the radars unusable with powerful electronic jammers.

The commander of the *Midway*'s air wing made the decision. He needed the pilot, so he would sign a waiver and the nugget would fly. He would gamble that the new pilot could get the airplane back aboard without killing anybody. The nugget goes through living hell on that first flight—a hell that includes a near-disastrous tanking with an Air Force KC-135 and a heart-stopping approach that almost terminates in a fiery collision.

Despite a case of "sewing-machine leg" and a chewing out by a senior pilot named Mad Dog, the nugget is allowed to continue his training flights, and he soon flies off to participate in Desert Storm. He sees anti-aircraft fire across the nose, but it diminishes when the operational altitude goes up to 20,000 feet. He encounters at least one "telephone pole" missile fired in the vicinity, and there is one genuine, gut-crunching moment of terror as a stray F-14 comes out of the night and barely slithers past his canopy.

But in this war the nugget is lucky. The bandits that could have blown his defenseless airplane out of the sky were missing in action. And his mission did not call for him to dive into the deadly clouds

of tracers from the ZSU-23-4s or to trespass into the kill zone of the hand-held surface-to-air missiles that snake upward.

The nugget is transformed into a war veteran, but one who leaves the Persian Gulf fully aware of his true status and his modest piloting skills. Back home, he wins the girl whose letters had spiced up his life.

Ironclaw has none of the savagery and action that Jake Grafton experienced in *Flight of the Intruder*—action that left this reviewer with sweaty palms. Nonetheless, this tale, told with candor and modesty, is

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a fine account of what it is like to be young and in love and engaged in the hazardous business of flying airplanes from carriers.

—William Smallwood has written extensively about the Gulf war.

Brassey's Encyclopedia of Military History and Biography, *edited by Franklin D. Margiotta. Brassey's, 1994. 1,232 pp. $44.95 (hardcover).*

This historic survey, covering the great military players and campaigns of recorded time, extends some 3,500 years from the early Assyrians to the Gulf war. Given that time span, aerospace-related matters can hardly be expected to occupy a dominant sector of this most useful volume. Even so, Colonel Frank Margiotta, former fighter pilot and B-52 commander, has done a splendid job of insuring that the exploding importance of air power in the 20th century is given thoughtful coverage.

Starting with Italian general Giulio Douhet, the original prophet of military dominance through strategic bombing, the book describes the challenge of exploiting the growth of aeronautical capabilities. Chapters cover the likes of Generals "Hap" Arnold and "Tooey" Spaatz. The subjects "airpower" and "space warfare" are treated separately.

The subjects are presented not chronologically but alphabetically and are thoroughly indexed and cross-referenced. The material is a condensation of six large volumes of a more comprehensive encyclopedia. It is well written and very well edited. In an era when speed of production seems to take precedence over careful weeding out of glitches, this volume is a special pleasure for the reader easily offended by careless editorial oversight.

There is one unfortunate omission. The book's account of the Korean war mentions the Mikoyan MiG-15, the Lockheed P-80, and the North American P-51 but not the North American F-86 Sabre, which enjoyed a six-to-one advantage over the MiG-15 in aerial combat; some believe its advantage was as great as 10 to one.

Overall, however, both the amateur history buff and the serious student of man's seemingly ceaseless conflict will find this is a most useful book.

—Former North American test pilot Al Blackburn spent a lot of time wringing out F-86 Sabres.

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CREDITS

The Grumman on the Moore Farm. Bernard Ryan Jr. is the author of 18 books on such wide-ranging subjects as crime, childhood education, financial planning, and advertising. He lives in Southbury, Connecticut.

Pepsi's Air War. Frequent contributor Lester A. Reingold harbors no hopes of acquiring a combat aircraft with Pepsi points, since his beverage of choice is Diet Coke.

Saturn Rising. Frank Winter is curator of rocketry at the National Air and Space Museum. He has written extensively on pre-Space Age rocketry.

Scott Wirz works as a technician for the National Air and Space Museum's collections management department.

Based near Washington, D.C., Scott Andrews specializes in aerospace and remotely controlled photography; he designs and builds many of the camera systems that he uses. He has photographed nearly every space shuttle mission, as well as the launches of spacecraft the world over. Andrews attributes his fascination with spaceflight to watching the early Mercury launches.

Escape to U Taphao. Ralph Wetterhahn flew fighters for both the Air Force and the Navy during the Vietnam war. He learned to speak Thai and Lao while living and writing in Asia. Now he resides in—and flies out of—Long Beach, California.

Known for his automotive art and also for his command of the water color medium, Ken Dallison has done work for *Sports Illustrated*, *Car & Driver*, *National Geographic*, *Esquire*, and *Redbook*.

The Rotary Cup. Burbank, California writer Preston Lerner's last feature for *Air & Space/Smithsonian* was "Single Stage to...Where?" (Feb./Mar. 1994).

A resident of Mystic, Connecticut, photographer Michael Melford overcame his fear of flying by getting a private pilot's license. Now he loves to hang out of airplanes and helicopters all over the world. He has just published his first book, *Big Sky Country* (Rizzoli).

Deliverance. T.A. Heppenheimer is an associate fellow of the American Institute of Aeronautics and Astronautics.

Burial at Sea. Erik Hildebrandt has been closely following naval aviation operations for the past year. He recently completed a coffee table book on the subject entitled *Blue Water Ops* (Howell Press), due in bookstores by spring 1997.

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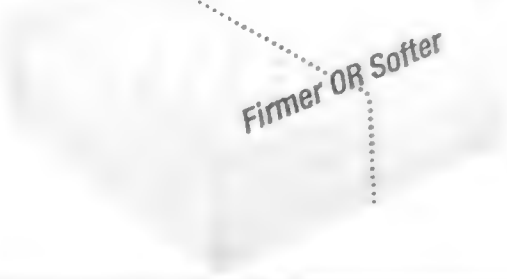

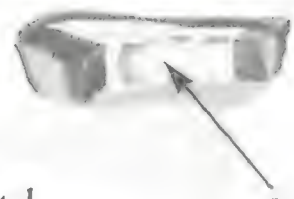

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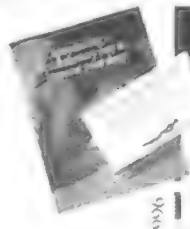

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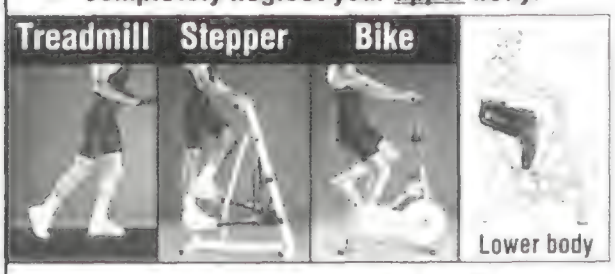

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CREDITS

Power Struggle. A resident of Belleville, Michigan, Don Sherman writes for *Popular Science* and *Motor Trend*. When he isn't road-testing a new model, he can be found restoring a 1967 Corvette powered by a mass-produced version of the Thunder/Orenda V-8.

United We Orbit. James E. Oberg is a space engineer at NASA's Johnson Space Center in Houston. His article "Rendezvous in Space" ran in the Aug./Sept. 1993 issue.

On the Lighter Side. Lance Thompson is a frequent contributor to Collections. He is presently working on episodes for the 1997 season of "Terry and the Pirates," a television series based on the classic comic strip.

CALENDAR

Through January 5
"Building for Air Travel: Architecture and Design for Commercial Aviation." Examining the design of airports and airliners from the 1920s on, this exhibit features numerous archival photographs, cutaway models of the Boeing 307 and 314 airliners, and drawings of airports under construction. Art Institute, Chicago, IL, (312) 443-3600.

December 7
"Pearl Harbor: Was There a Conspiracy?" A symposium featuring Pearl Harbor historian Captain Jim Johns, U.S. Army (ret.). Planes of Fame Air Museum, Eden Prairie, MN, (612) 941-2633.

December 14
"The British Spitfire," a symposium featuring historian Tom Lymburn. Planes of Fame Air Museum, Eden Prairie, MN, (612) 941-2633.

January 5–10
"Airports in the 21st Century: An Impending Crisis?" Sponsored by the University Aviation Association, this seminar will investigate strategies for meeting new demands on airport capacity. Holiday Inn-Capitol, Washington, DC, (703) 532-4954.

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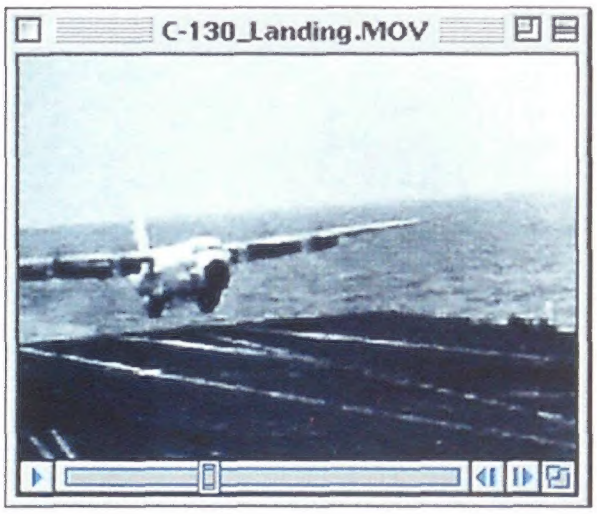

From our home page go to the "Sightings" feature to see footage of a Lockheed C-130 Hercules landing on the aircraft carrier U.S.S. *Forrestal.*

Climb into the cockpit of the P-51 Mustang *Miss America* and examine this Unlimited-class racer from the pilot's point of view.

For another Web feature, "Talking with Diane," *Air & Space* associate editor Diane Tedeschi interviewed Colonel Donald S. Lopez, U.S. Air Force (ret.), now the deputy director of the National Air and Space Museum. During World War II, Lopez flew his Curtiss P-40 with the 14th Air Force's 23rd Fighter Group, which was based in China. After the war, he worked as a test pilot at Eglin Field (now Air Force Base) in Florida. Read Lopez's sometimes funny, always riveting war stories, and view archival footage of P-40s flying in formation over China (www.airspacemag.com/TWD/TWD0002.html).

The *Air & Space* home page also features the Visitor Infobase, an all-purpose bulletin board and clearinghouse for air- and space-minded visitors looking for others with similar interests. You can arrange online chat sessions or video conferences, find other players for online games, and organize reunions, meetings, and fly-ins.

In Spacebeat, veteran space reporter and *Air & Space* contributing editor Greg Freiherr takes visitors on a tour of the aerospace world, dropping in on current missions and programs.

FORECAST

In the Wings...

The Last of the Mohawks. The Grumman OV-1 Mohawk first flew with the U.S. Army in 1957. After nearly four decades of bringing back intelligence from the battlefield or demilitarized zone—in Vietnam, Korea, Europe, Iraq—the Mohawk finally flew its last mission.

Slick Six. Space Launch Complex 6—SLC-6—has been standing by, ready for duty, since 1968. It was built for Titans and refurbished for space shuttles but has yet to host a successful launch. Is it cursed?

William Mayfield's Lucky Break. You might say that being a staff photographer at the Dayton *Daily News* in 1904 put young Bill Mayfield in the Wright place at the right time.

Airship City. In a town where everything from the main street to the corner drugstore is named after its favorite son—Ferdinand Graf von Zeppelin—guess what aeronautical mode of transportation the city has decided to revive?

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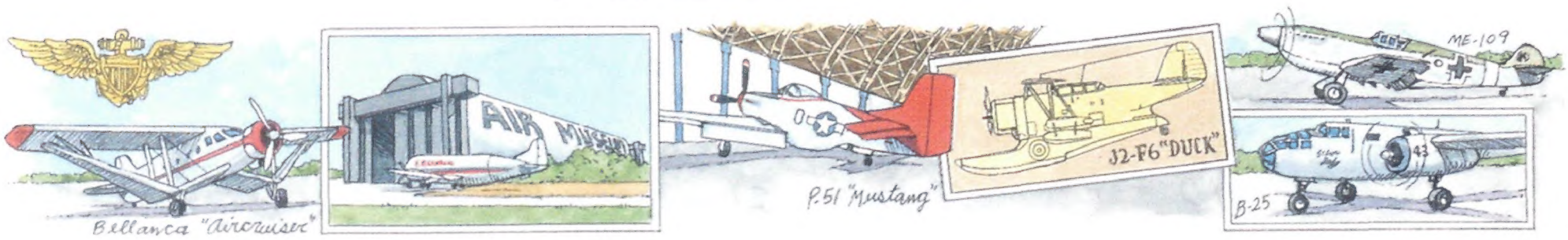

JOHN HEINLY

On the Lighter Side

Signs along the highway alert drivers that the Tillamook Naval Air Station Museum is coming up in a few miles, but there's really no danger of missing it. Originally a Navy blimp hangar, the giant building dominates its pastoral Oregon setting. On its side the words "AIR MUSEUM" are emblazoned a hundred feet high.

But the structure's vast dimensions don't register fully until you enter the awesome, cathedral-like interior. The vastness overwhelms the classic aircraft displayed inside, making them look like quarter-scale models. The building's entire wooden skeleton stands exposed, a monument in Douglas fir to the men who built it. Their achievement looks all the more impressive to visitors who stare up at the narrow catwalks and near-vertical stairways that cling to the gracefully curved structure 170 feet overhead.

The hangar was one of 17 built when the United States entered World War II. Charged with patrolling the U.S. coasts, the Navy began mobilizing a fleet of non-rigid airships, or blimps. The craft were to be based in hangars of massive proportions: over a thousand feet long and with a roof area of more than 11 acres. To accommodate the blimps, the hangars could have no internal poles, columns, or support struts—they had to be what engineers call "clear span" structures.

Such immense buildings are usually built of steel, since it can provide the necessary stability, but during the war the nation's appetite for the metal had grown insatiable, so the hangars built at that time had to be made of concrete and wood.

The Navy came up with an ingeniously simple design. For each hangar, 51 wooden arches would be constructed and lined up, and the whole assembly would then be covered with a roof. The Navy contracted with Timber Structures, Inc., of Portland, Oregon, to produce the components for most of the hangars. "They fabricated everything, pre-bored all the holes, and shipped it out just like an Erector Set," explains engineer Don Neal, who worked at Timber Stuctures after the blimp era. Each hangar had two million board-feet of lumber. Back then, the structures were the largest clear-span wooden buildings in the world.

The Navy installed two hangars at Tillamook to house the blimps that would fly patrolling missions along the north Pacific coast. Construction stretched through one of the harshest winters on record, with over 18 inches of rain and the first snowfall in 30 years. The ground was so marshy that as soon as holes were dug, they filled with water.

Tillamook Naval Air Station Museum, 6030 Hangar Road, Tillamook, OR 97141. Phone (503) 842-1130. Open 10 a.m.–5 p.m., Nov.–Apr.; 9 a.m.–6 p.m., May–Oct. Adults, $5; kids 7–12, $2.50; under 6, no charge.

The hangars were completed in 1943, and for the next two years, about 15 blimps were based at Tillamook Naval Air Station, providing anti-submarine patrols for ship convoys passing to and from ports in Oregon and Washington. On a typical eight- to 10-hour patrol, a blimp cruising along at 55 mph could cover 13,000 square miles of ocean. Armed with depth charges and machine guns, the Navy's K-class blimps made ideal anti-submarine escorts. No convoy escorted by a U.S. Navy blimp ever lost a ship in World War II.

After the war, the Navy used the Tillamook hangars for temporary storage of surplus aircraft, then disbanded the base. In the years since, the hangars were leased as warehouses, lumber mills, wood-veneer plants, and housing for private companies' airships.

In 1992, the local port authority set up a modest little museum in one of the hangars (the other burned down in a fire that year). The following year, the museum's holdings dramatically expanded when Oregon businessman Jack Erickson put his private collection of warplanes on display there. Since then, the Smithsonian, the Navy, and private collectors have also lent aircraft.

The better-known artifacts include a B-25 Mitchell bomber, a P-51 Mustang, a Messerschmitt Bf 109, and a PBY-5A Catalina amphibian. But the collection is eclectic: There's a J2F-6 Grumman "Duck"—a World War II amphibious utility craft with a protruding banana-like hull—as well as a rare Martin AM-1 Mauler, a Navy airplane designed during World War II to carry guns, rockets, bombs, or torpedoes. (The Mauler turned out to be so problem-prone that only 151 were produced.) There's a 1935 Bellanca Aircruiser biplane, an old favorite of Canadian bush pilots that has a jazzy "W"-shaped bottom wing. And parked outside is a bulbous Boeing 377 "Mini-Guppy" transport. Best of all, there are no barriers around the aircraft, so visitors can walk right up and get a good look.

Under the museum's bent-wing Corsair, a coffee can collects oil dripping from the Pratt & Whitney Double Wasp radial engine. The airplanes in the museum are more than just artifacts—these are operational aircraft in a working hangar. During the summer, the museum holds flying exhibitions of various airplanes about twice a month.

The museum still rents hangar space to airship companies, so modern blimps provide a lighter-than-air backdrop for the collection's warplanes. Though smaller than the blimps originally based here, the contemporary airships still give visitors a sense of what it might have been like to gaze up at a cluster of blimps dutifully plodding along, like a military version of the Macy's Thanksgiving Day Parade.

Even without blimps, the building itself is a wonder, one of only seven wooden blimp hangars left standing. It has survived a fire (in 1955), 125-mph winds, and over a half-century of use. "They couldn't do it today," Don Neal says of the construction project. "It's one of those impossible things that only gets done in wartime."

—Lance Thompson

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Captain Steve Wand, Concorde pilot and Senior Training Captain, at the controls of the Concorde simulator.

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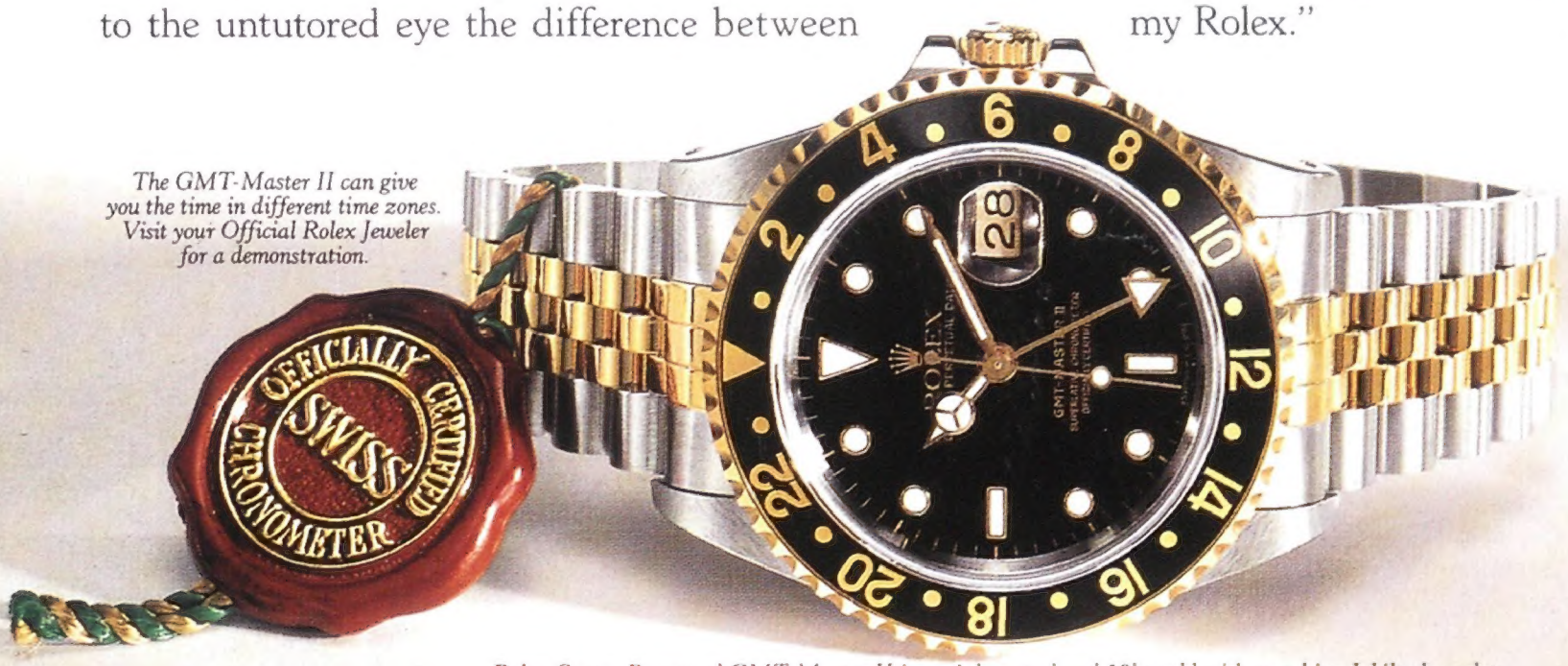

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